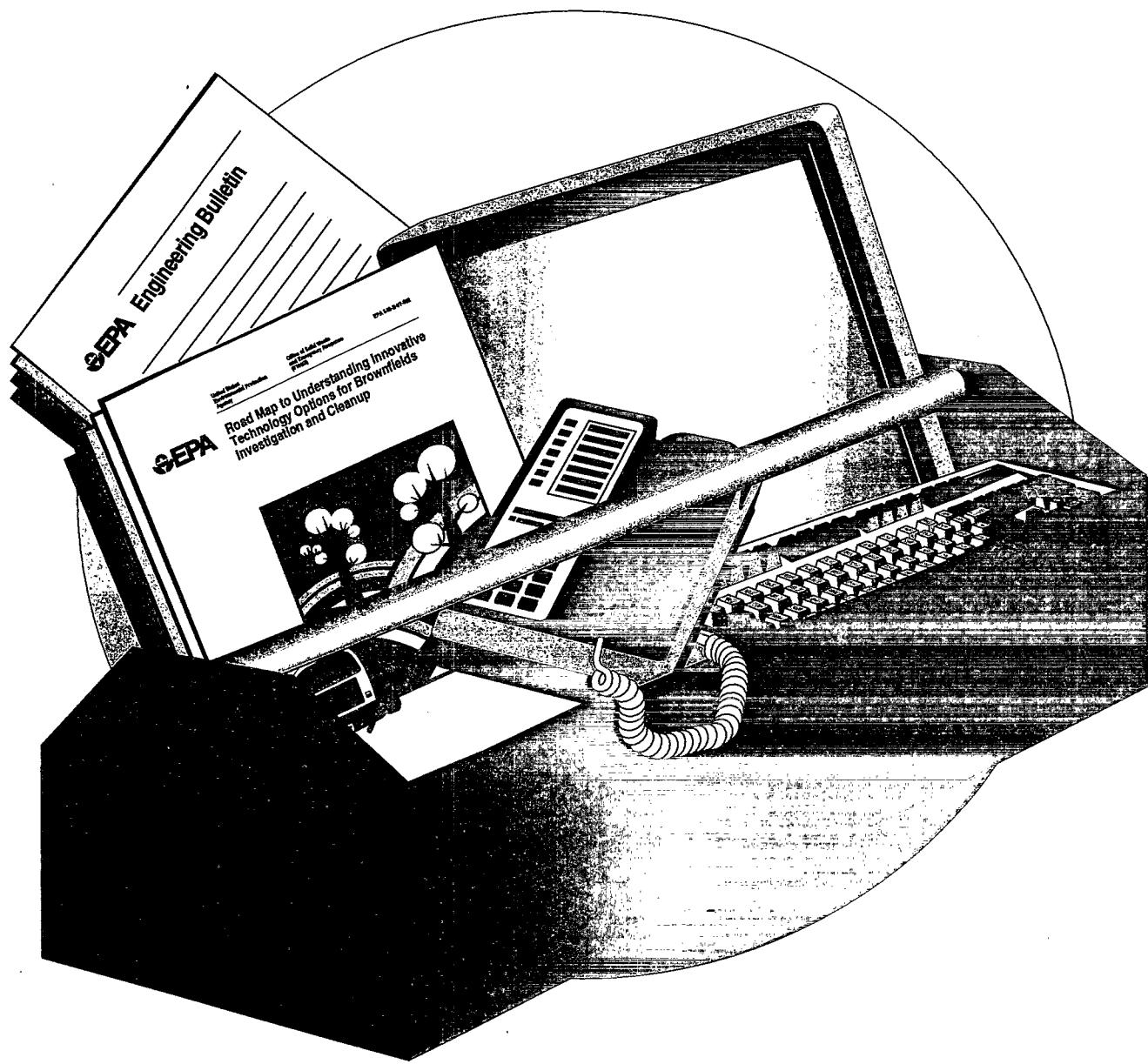


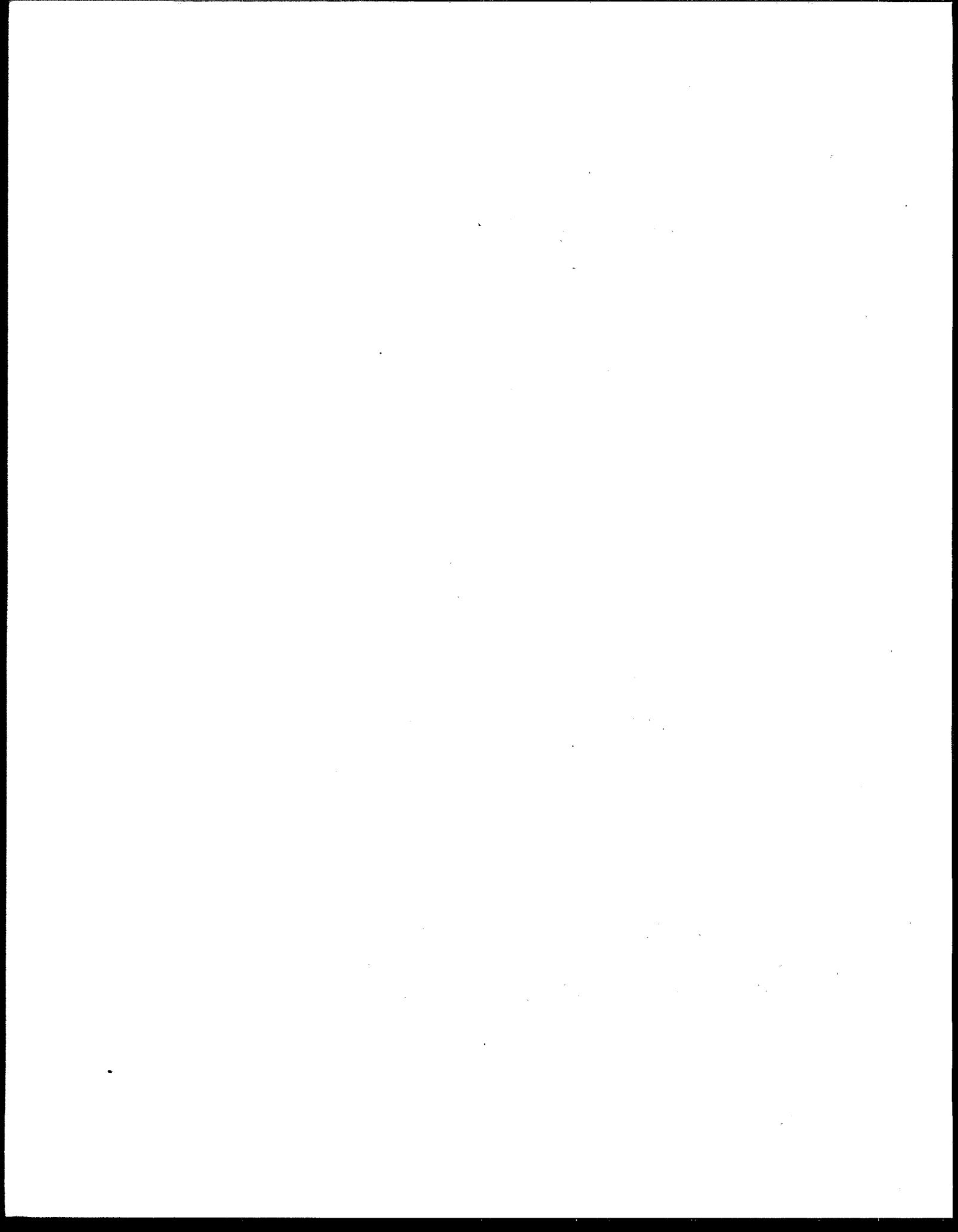


Tool Kit of Information Resources for Brownfields Investigation and Cleanup



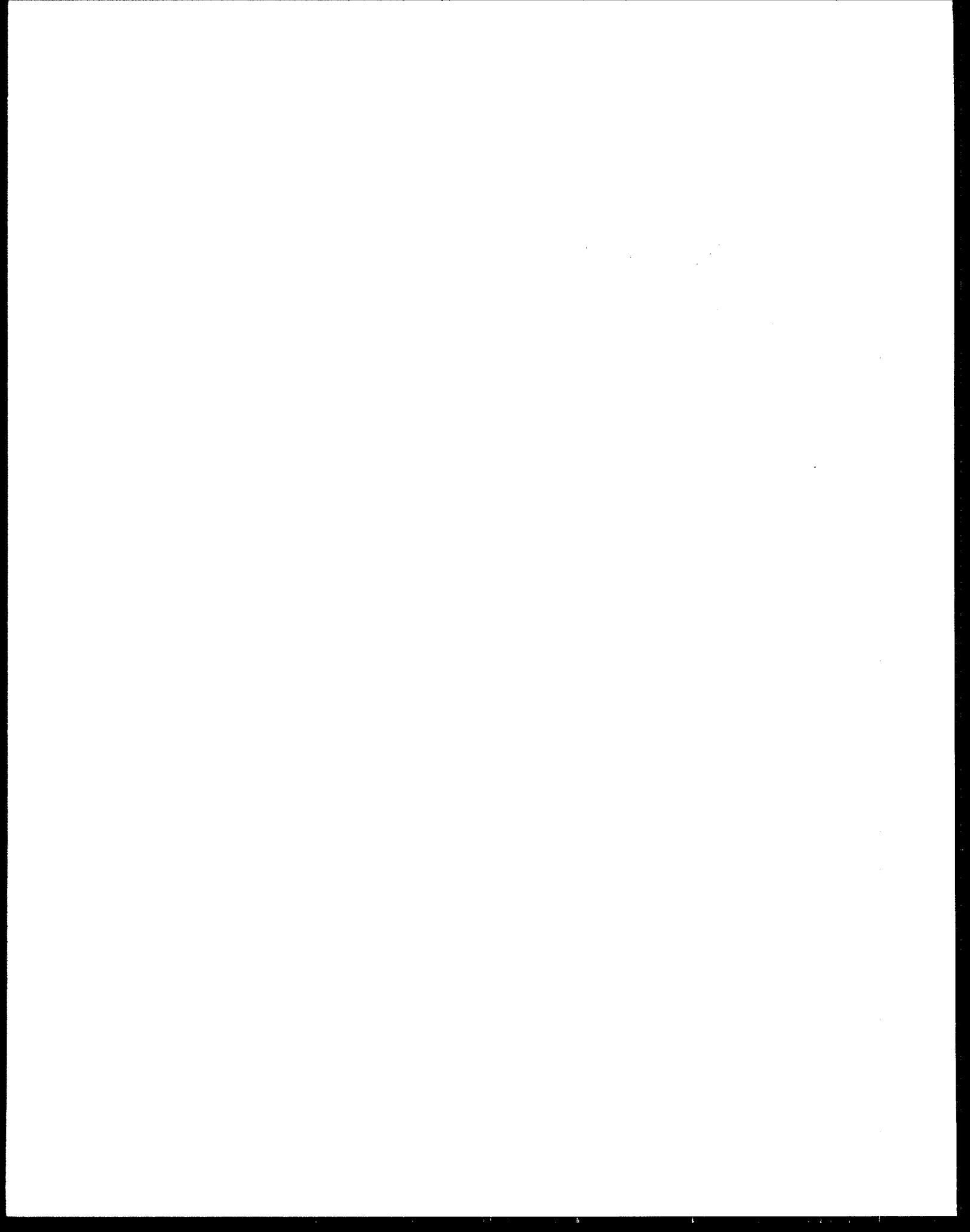
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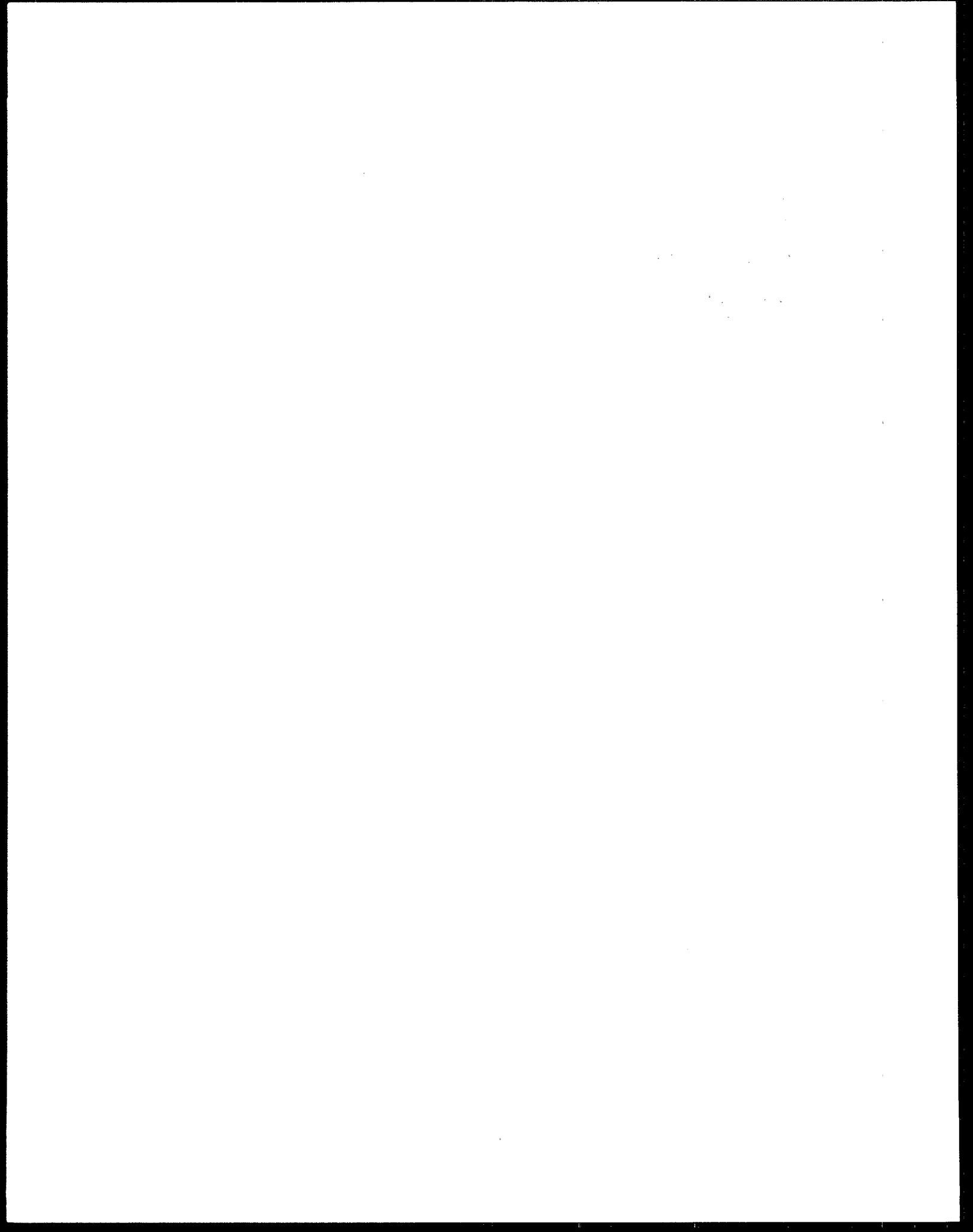
Tool Kit of Information Resources for Brownfields Investigation and Cleanup

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460



NOTICE

This document has been funded by the United States Environmental Protection Agency (EPA) under Contract 68-W5-0055 to PRC Environmental Management, Inc. The document was subjected to the Agency's administrative and expert review and was approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.



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BACKGROUND

The U.S. Environmental Protection Agency (EPA) has defined Brownfields sites as "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination."

EPA established its Brownfields Economic

Redevelopment Initiative to empower states, communities, and other stakeholders involved in economic revitalization to work together to accomplish the redevelopment of such sites. Many states and local jurisdictions also help business and communities adapt environmental cleanup programs to the special needs of Brownfields sites.



Preparing Brownfields sites for productive reuse requires the integration of many elements—financial issues, community involvement, liability considerations, environmental assessment and cleanup, regulatory requirements, and more—as well as coordination among many groups of stakeholders. The assessment and cleanup of a site must be carried out in a way that integrates all those factors into the overall redevelopment process. In addition, the cleanup strategy will vary from site to site. At some sites, cleanup will be completed before the property is transferred to new owners. At other sites, cleanup may take place

simultaneously with construction and redevelopment activities. Regardless of when and how cleanup is accomplished, the challenge to any Brownfields program is to clean up sites quickly and redevelop the land in ways that benefit communities and local economies.

Numerous technology options are available to assist those involved in Brownfields cleanup. EPA's Technology Innovation Office (TIO) encourages the use of innovative and cost-effective technologies to characterize and clean up contaminated sites. Innovative technologies for evaluating the nature and extent of contamination and for addressing the cleanup of Brownfields sites hold promise for reducing the cost of cleanup and accelerating the cleanup schedule—potentially producing significant benefits to Brownfields stakeholders by reducing barriers to redevelopment that add to costs, or time schedules, or create uncertainties. When such

factors as lower cost, increased environmental protection, and improved effectiveness are considered, innovative technologies frequently are more cost-effective and provide better and more efficient cleanup than established treatment technologies. Often, they also are more acceptable to communities.

Innovative does not mean unproven. EPA defines an innovative technology as one that has been used in the field but that is not yet considered routinely for use. In addition, cost and performance data on the technologies may be insufficient to encourage managers of cleanup projects to select those technologies over established methods.

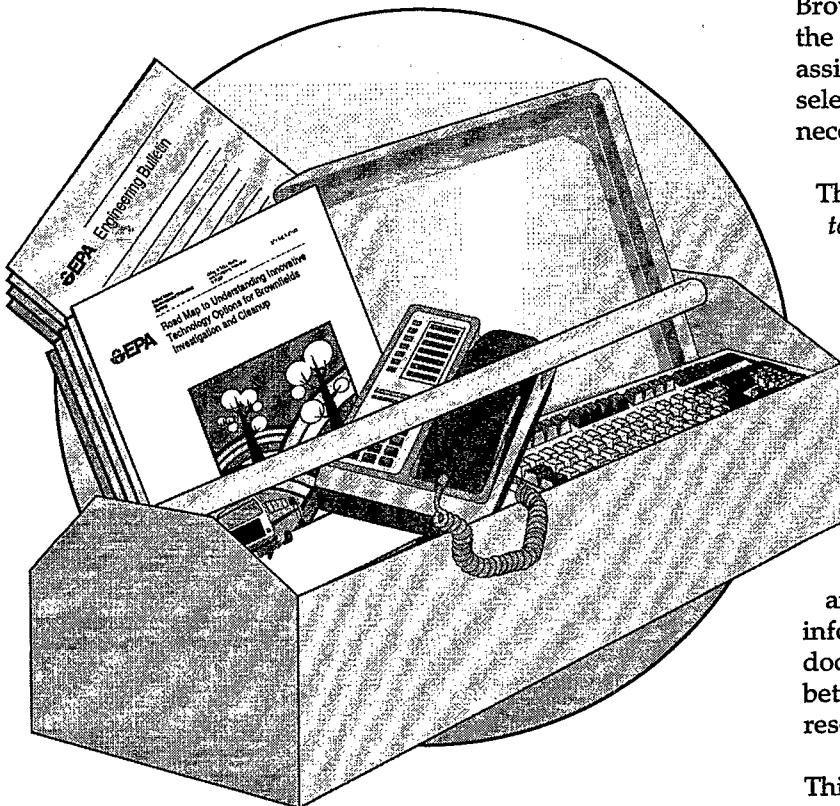
Nevertheless, innovative technologies are being used in many cleanup programs to assess contamination and to treat a variety of hazardous substances and petroleum products that have been released into the environment. For example, approximately 43 percent of Superfund sites that have contaminated soil are using "innovative" technologies (*Innovative Treatment Technologies: Annual Status Report, Eighth Edition*).

An Emerging Technology is an innovative technology that currently is undergoing bench-scale testing, in which a small version of the technology is tested in a laboratory.

An Innovative Technology is a technology that has been field-tested and applied to a hazardous waste problem at a site, but lacks a long history of full-scale use. Information about its cost and how well it works may be insufficient to support prediction of its performance under a wide variety of operating conditions.

An Established Technology is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established.

INTRODUCTION



The Tool Kit of Information Resources for Brownfields Investigation and Cleanup focuses on the site characterization and cleanup phase of Brownfields redevelopment. It introduces Brownfields stakeholders to the range of technology options and resources available to them. This Tool Kit provides abstracts and access information about a variety of resources, including electronic databases, bulletin boards, newsletters, regulatory and policy guidance, and technical reports, that may be useful to Brownfields stakeholders as they proceed through the cleanup process. The Tool Kit is intended to assist Brownfields stakeholders involved in the selection of technologies in assessing, and, if necessary, addressing contamination at their site.

The Tool Kit is a companion guide to the *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup*, also developed by TIO. The Road Map provides a framework of the four basic phases of the characterization and cleanup of a Brownfields site—Site Assessment, Site Investigation, Cleanup Options, and Cleanup Design and Implementation—and links technology options and resources to each of those steps. The Tool Kit, in turn, describes the resources identified in each step in the Road Map, provides information about how to obtain them, and provides a “starter kit” of important information resources. Used in tandem, the two documents should help Brownfields stakeholders better understand the technology options and resources available to them.

This Tool Kit is intended for the various individuals involved in or affected by the redevelopment of Brownfields sites. It specifically focuses on those who will make decisions about Brownfields sites but may not be familiar with many of the elements involved in cleaning them up. The document seeks to create an “educated consumer” by introducing the decision makers to the full range of technology information and resources available. In addition, since most Brownfields sites will not be subject to the provisions of such Federally mandated programs as Superfund, the Tool Kit, along with the Road Map, introduces Brownfields stakeholders to the steps involved in implementing a cleanup. To better understand those steps, stakeholders should consult as early as possible with the appropriate regulators at the state and, if necessary, at the

Federal level. Stakeholders can obtain additional information and assistance by working with reputable technical and legal experts. A qualified site cleanup professional from a reputable consulting and engineering firm also may be employed.

It is important to understand that the cleanup process may not occur in the sequence outlined in the following chapters. At many sites, several activities may be undertaken concurrently with other phases. It is important to consider during each phase the activities and requirements described for subsequent phases, as well as to determine whether activities can be combined or implemented concurrently.

How to Use the Tool Kit

The first four sections of the Tool Kit identify the four phases of the cleanup of potentially contaminated sites: site assessment, site investigation, assessment of cleanup options, and design and implementation of the remedy. Each section describes the objective to be accomplished, summarizes the activities undertaken during that phase, and then provides detailed descriptions of information resources available to help Brownfields stakeholders understand technology options applicable at that phase. The last section, "Other Important Considerations and Resources," discusses additional factors that affect the cleanup of Brownfields sites and lists applicable resources, including hotlines and other services.

Several appendices also are included to help Brownfields stakeholders understand technical terms and issues related to cleanup. *Appendix A, Brownfields Site Cleanup "Starter Kit,"* provides several important resources to give Brownfields stakeholders examples of the materials available to assist their cleanup and redevelopment efforts. *Appendix B, List of Acronyms and Glossary of Key Terms,* defines special terms and acronyms used in discussing and describing Brownfields cleanup efforts. *Appendix C, List of Brownfields and Technical Support Contacts,* provides information about state and EPA regional and technical points of contact. *Appendix D, How to Order Documents,* provides information about ordering the documents listed in the Tool Kit, as well as order forms.

How to Submit Comments

To help ensure that any future versions of the document meet the needs of its intended audience, EPA invites comments from the members of the Brownfields community. Please submit comments to:

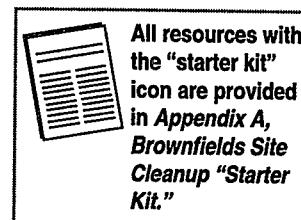
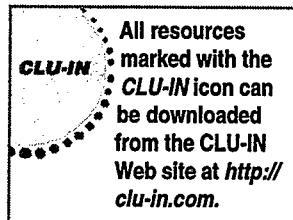
Brownfields Tool Kit
U.S. Environmental Protection Agency
Technology Innovation Office
401 M Street, SW (MC 5102G)
Washington, DC 20460
E-mail: powell.dan@epamail.epa.gov
Fax: (703) 603-9135

How to Obtain Additional Copies

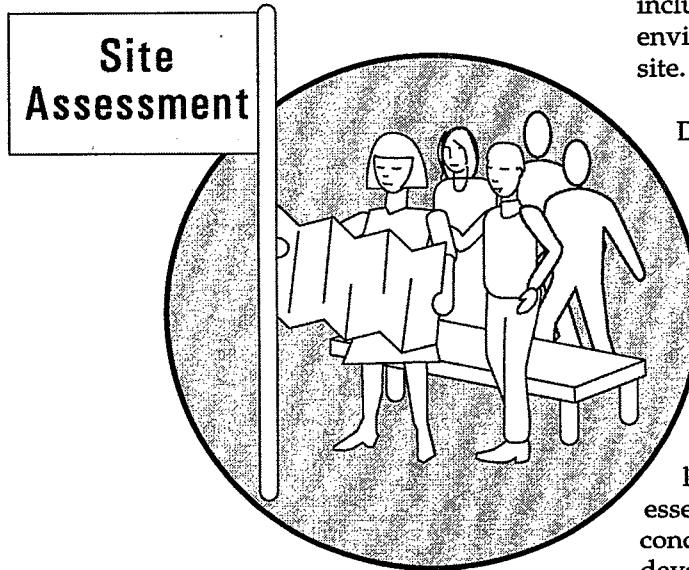
Additional copies of this document can be obtained from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

When ordering, refer to document number PB97-144828 for the Tool Kit and document number PB97-144810 for the Road Map.



SITE ASSESSMENT RESOURCES



Collect and Assess Information About the Brownfields Site

The purpose of this step is to determine the likelihood of contamination at a particular site by collecting and reviewing applicable information about a site. This "environmental audit" is an initial investigation that usually is limited to a search of historical records. The data to be collected also include information about past and current environmental conditions and historical uses of the site.

During the site assessment phase, it is important to consider the activities and requirements described in the subsequent chapters and determine how they can be combined with or initiated during the site assessment. The collection of data during this initial step of the cleanup process is extremely important for use in identifying and evaluating the applicability of site assessment and cleanup technologies, as well as in determining whether the property can be cleaned to the level necessary for its intended reuse. It also is essential to assess and address the needs and concerns of the community (for example, the development of social and economic profiles and the identification of acceptable environmental risk).

To ensure that sufficient data are collected, the potential applicability of innovative technologies to the site also should be considered. Since much of the work at this stage involves a search of paper and electronic records, applicable technology options may be somewhat limited.

Listed below are information resources that can assist Brownfields stakeholders in conducting an initial assessment of the environmental conditions at a site.

Resources

A. Technology Survey Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies and status reports. A bulletin board system designed for the exchange of information also is included.



CLU-IN Clean-Up Information (CLU-IN) Bulletin Board System. The system is designed for use by hazardous waste cleanup professionals who need current information on innovative technologies for remediation and access to EPA publications, other regularly updated information, and databases. CLU-IN can be accessed by modem at (301) 589-8366 or through the Internet at <http://clu-in.com>. Assistance can be reached at (301) 589-8368.

 A copy of the CLU-IN brochure is provided on page A-91 in Appendix A, *Brownfields Site Cleanup "Starter Kit."*

CLU-IN Clean-Up Information Home Page on the World Wide Web (EPA 542-F-96-011). The home page provides information about innovative treatment technologies to the hazardous waste remediation community. It describes programs, organizations, publications, and other tools for EPA and other Federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. The home page can be accessed through the Internet at <http://clu-in.com>.

National Exposure Research Laboratory—Las Vegas, Site Characterization CD-ROM (EPA 600-C-96-001).

The CD-ROM, developed by EPA's National Exposure Laboratory (NERL) - Las Vegas, Characterization Research Division, compiles guidance documents and related software to aid environmental professionals in the complex, multidisciplinary characterizing of hazardous waste sites. The CD-ROM, a compilation of computer programs and documents developed by EPA, includes more than 3,200 pages of documents related to EPA's Resource Conservation and

Recovery Act (RCRA) and Superfund programs that can be printed, as well as searched by key words. Using the CD-ROM requires a personal computer with DOS Version 3.0 or higher, 640K of RAM, and 3MB hard disk space. A math coprocessor is recommended but not required. The CD-ROM can be purchased from the National Technical Information Service (NTIS) for \$135.00 (see the order form in Appendix D, *How to Order Documents*). The CD-ROM contains the following documents and software:

- *Bibliography of Groundwater Sampling Methods*
- *Compendium of Superfund Program Publications (EPA 540-8-91-014)*
- *Data Quality Objectives Process for Superfund (EPA 540-R-93-071)*
- *Description and Sampling of Contaminated Soils: A Field Pocket Guide (EPA 625-12-91-002)*
- *Field Screening Methods Catalog (EPA 540-2-8-005)*
- *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 540-G-89-004)*
- *Guidance for Performing Preliminary Assessments Under CERCLA (EPA 540-G-91-013)*
- *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells (EPA 600-4-89-034)*
- *Preliminary Assessment Guidance for FY88 (OSWER 9345.0-01)*
- *Preparation Aids for the Development of Category I Quality Assurance Project Plans (EPA 600-8-91-003)*
- *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies (EPA 600-R-92-129)*
- *RCRA Groundwater Monitoring Technical Enforcement Guidance Document (OSWER 9950.1)*
- *Soil Sampling Quality Assurance User's Guide (EPA 600-8-89-046)*
- *Superfund Exposure Assessment Manual (EPA 540-1-88-001)*

- *Vadose Zone Monitoring for Hazardous Waste Sites (EPA 600-X-83-064)*
- *ASSESS Version 1.1A (PB93-505154)*. ASSESS is an interactive quality assurance and quality control (QA/QC) program designed to assist the user in statistically determining the quality of data from soil samples.
- *Decision Error Feasibility Trials (DEFT) Version 4.0*. The DEFT software allows a decision maker or member of a planning team to quickly generate cost information about several sampling designs based on data quality objectives (DQO). A user's guide is available on the CD-ROM.
- *Geostatistical Environmental Assessment Software (Geo-EAS) Version 1.2.1 (PB93-504967)*. Geo-EAS offers environmental scientists an interactive tool for performing two-dimensional geostatistical analyses of spatially distributed data. Extensive use of screen graphics such as maps, histograms, scatter plots, and variograms helps the user search for patterns, correlations, and problems in a data set. A user's guide also is available on the CD-ROM.
- *Geophysics Advisor Expert System Version 2.0 (PB93-505162)*. The program considers several geophysical methods of determining the location of contamination and providing site characterization to make recommendations on the best methods to use at a specific site. Version 2.0 also includes a database of the physical and chemical properties of 94 substances selected from EPA's National Priorities List (NPL).
- *Scout Version 2.0*. Scout is a user-friendly and menu-driven program that provides a graphical display of data in a multidimensional format that allows visual inspection of data, accentuates obvious outliers, and provides an easy means of comparing one data set with another. A user's guide also is available on the CD-ROM.

B. Site-Specific Resources

Listed below are survey reports on the application of innovative technologies to specific contaminants and site types. PC-based searchable databases also are included.

Contaminants and Remedial Options at Pesticide Sites (EPA 600-R-94-202, PB95-183869).

The document provides information about treatment technologies and the selection of services at pesticide sites to meet acceptable levels of cleanliness as required by applicable regulations. It is targeted primarily for the use of Federal, state, or private site removal and remediation managers. The document does not identify or establish cleanup levels.

Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 540-R-95-512, PB95-271961).

The report provides information on site characterization and the selection of treatment technologies capable of meeting site-specific cleanup levels at sites contaminated with metal. It is targeted to Federal, state, and private site removal and remediation managers. The report focuses primarily on metalloid arsenic and metals, including cadmium, chromium, lead, and mercury. The report does not identify or establish cleanup levels.

Contaminants and Remedial Options at Solvent-Contaminated Sites (EPA 600-R-94-203, PB95-177200).

The document provides information about the selection of treatment technologies and services to meet established cleanup levels at solvent-contaminated sites. It will assist Federal, state, or private site removal and remediation managers operating within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA, or state rules. The document is designed to be used with other guidance documents. The document does not provide risk assessment information or policy guidance related to determining cleanup levels.

Contaminants and Remedial Options at Wood Preserving Sites (EPA 600-R-92-182, PB92-232222).

The report provides information on site characterization and selection of treatment technologies capable of meeting site-specific

cleanup levels at wood preserving sites. It is targeted to Federal, state, and private site removal and remediation managers. The report focuses primarily on chemicals associated with wood preserving processes—pentachlorophenol, creosote, fire retardants, and water and ammonia solutions of copper, chromium, arsenic, and zinc.

Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA 510-B-97-001).

Produced by EPA's Office of Underground Storage Tanks (OUST), this guide is designed to help state and Federal regulators with responsibility for underground storage tanks (UST) to evaluate conventional and new site assessment technologies and promote the use of expedited site assessments. The manual covers five major issues related to UST site assessments: the expedited site assessment process; surface geophysical methods for UST site investigations; soil-gas surveys; direct push technologies; and field analytical methods for the analysis of petroleum hydrocarbons. The equipment and methods presented in the manual are evaluated in terms of applicability, advantages, and limitations for use at petroleum UST sites.

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews. PC-based searchable databases also are included.

CLU-IN Consortium for Site Characterization Technology—Innovative Technology Verification Reports (Fact Sheet EPA 542-F-96-012).

The Consortium for Site Characterization Technology (CSCT) is a partnership program involving EPA, the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE) that is responsible for evaluating and verifying the performance of innovative site characterization technologies. The CSCT provides technology support to technology developers, evaluates and verifies data generated during demonstrations, and develops and disseminates information about the performance of site characterization technologies. The fact sheet describes the mission

of the Consortium and its activities and identifies points of contacts. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The Consortium is in the process of finalizing verification statements and accompanying reports for 12 technologies in three technology categories: Cone Penetrometer/Laser Induced Fluorescence (LIF), Field-Portable X-Ray Fluorescence (FPXRF), and Portable Gas Chromatograph/Mass Spectrometers (GC/MS). Innovative technology verification reports for two in situ laser-induced fluorescence-based technologies, Site Characterization and Analysis Penetrometer System (SCAPS) and the Rapid Optical Screening Tool (ROST), are now available. The reports listed below document the demonstration activities, and present and evaluate the demonstration data to verify the performance of the tested technologies relative to claims of the developers:

- Cone Penetrometer/Laser Induced Fluorescence (LIF)
- Rapid Optical Screening Tool (ROST) (EPA 600-R-97-020)
- Site Characterization and Analysis Penetrometer System (SCAPS) (EPA 600-R-97-019)
- Field-Portable X-Ray Fluorescence (FPXRF)
- Portable Gas Chromatograph/Mass Spectrometers (GC/MS)

CLU-IN Vendor Field Analytical and Characterization Technologies System (Vendor FACTS), Version 2.0.

The Windows™-based system contains information provided by vendors on field-portable technologies for measuring and monitoring contaminated soil and groundwater. Some of the technologies listed in the system are air measurement technologies, analytical detectors, gas chromatography equipment, chemical reaction-based indicators, immunoassay instruments, and soil-gas analyzers. The system allows users to screen technologies by such parameters as contaminant, medium, or development status. Updated annually, the system can be downloaded from the Internet at <http://www.ttemi.com/vfacts> or from the CLU-IN Web site at <http://clu-in.com>.

 **Vendor FACTS Bulletin**
• (EPA 542-N-97-007).
CLU-IN The bulletin informs technology users of
• the composition of Vendor FACTS and
• technology vendors of the opportunities
Vendor FACTS can offer them. The bulletin
also provides information on obtaining copies of the
software and user manual, and system
requirements, as well as a registration and order
form. A list of the names of vendors, the types of
technology used, and the contaminants monitored
also is provided. The document can be downloaded
free of charge from the CLU-IN Web site at
<http://clu-in.com>.

 A copy of the Vendor FACTS Bulletin is
provided on page A-115 in *Appendix A,*
Brownfields Site Cleanup "Starter Kit."

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SITE INVESTIGATION RESOURCES



Identify the Source, Nature, and Extent of Contamination

The site investigation focuses on identifying, locating, and characterizing the nature and the extent of contamination (if it is present) at a Brownfields site. It is essential that an appropriately detailed study of the site be performed to identify the cause, nature, and extent of contamination and the possible threats to the environment or to any people living or working nearby. For Brownfields sites, the results of such a study can be used in determining goals for cleanup, quantifying risks, determining acceptable and unacceptable risk, and developing cleanup plans that do not cause unnecessary delays in the redevelopment and reuse of the property.

A site investigation is based on the results of the site assessment, which is discussed in the preceding section of the Tool Kit. The site investigation may include the analysis of samples of soil and soil gas, groundwater, surface water, and sediment. The migration pathways of contaminants also are examined during this phase, and a baseline risk assessment may be needed to calculate risk to human health and the environment.

The information resources listed below describe investigation methods and technologies for identifying the characteristics of a site.

Resources

A. Technology Survey Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies and status reports. A bulletin board system designed for the exchange of information also is included.



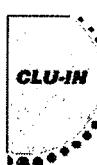
National Exposure Research Laboratory— Las Vegas, Site Characterization CD-ROM (EPA 600-C-96-001).

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 - *Description and Sampling of Contaminated Soils: A Field Pocket Guide* (EPA 625-12-91-002)
 - *Field Screening Methods Catalog* (EPA 540-2-8-005)
 - *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 540-G-89-004)
 - *Guidance for Performing Preliminary Assessments Under CERCLA* (EPA 540-G-91-013)
 - *Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells* (EPA 600-4-89-034)
 - *Preliminary Assessment Guidance for FY88* (OSWER 9345.0-01)
 - *Preparation Aids for the Development of Category I Quality Assurance Project Plans* (EPA 600-8-91-003)
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- Site Characterization and Monitoring:
 - Bibliography of EPA Information
 - Resources (EPA 542-B-96-001).
 - The bibliography lists information resources, both publications and electronic

databases, that focus on evaluation and use of innovative site characterization and monitoring technologies. The document also provides information on obtaining copies of the documents. The bibliography can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Status Report on Field Analytical Technologies Utilization, Fact Sheet (EPA 542-R-97-003).

The Office of Solid Waste and Emergency Response (OSWER) is creating a document that will report on the status of analytical and site characterization efforts that employ innovative field-portable technologies. The final report will identify the vendor, characterize the application, and list points of contact and references for additional information. The fact sheet, which describes the effort to develop data on past uses of the technologies, will help site managers identify projects at which the technologies have been used. The fact sheet also provides contact information and instructions for on-line access.

B. Site-Specific Resources

Listed below are survey reports on the application of innovative technologies to specific contaminants and site types. PC-based searchable databases also are included.

Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA 510-B-97-001).

Produced by EPA's Office of Underground Storage Tanks (OUST), this guide is designed to help state and Federal regulators with responsibility for underground storage tanks (UST) to evaluate conventional and new site assessment technologies and promote the use of expedited site assessments. The manual covers five major issues related to UST site assessments: the expedited site assessment process; surface geophysical methods for UST site investigations; soil-gas surveys; direct push technologies; and field analytical methods for the analysis of petroleum hydrocarbons. The equipment and methods presented in the manual are evaluated in terms of applicability, advantages, and limitations for use at petroleum UST sites.

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews. PC-based searchable databases also are included.

Abstract Proceedings: Superfund Technical Support Project General Meeting, Athens, Georgia 12/3/90 - 12/6/90 (PB93-205862).

The document is a collection of abstracts from a workshop on the Superfund Technical Support Project held in Athens, Georgia in December 1990. Several papers discuss technical issues, such as causes and effects of well turbidity; characterization of heterogeneous hazardous wastes; computer-aided assessment of contaminated sites; metal partitioning from incineration of soils and debris; and RCRA groundwater monitoring regulations. Other abstracts describe various programs, including the Superfund Technical Liaison Program, the Superfund Innovative Technology Evaluation (SITE) Program, and the U.S. Army Corps of Engineers laboratory support program for EPA regions. In addition, other summaries provide information about the Remedial Response Construction Cost Estimating System (RACES) and other databases. Fourier Transform Infrared Spectroscopy (FT-IR) and the MINTEQA2 Geochemical Equilibrium Model are described in other abstracts, along with a range of issues related to technical support for Superfund.

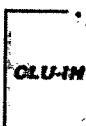
Characterization of Chromium-Contaminated Soils Using Field-Portable X-Ray Fluorescence (PB94-210457).

In 1990, EPA, the U.S. Coast Guard, and the Robert S. Kerr Environmental Research Laboratory initiated a cooperative effort to evaluate various methods of site characterization at sites contaminated with metals, particularly chromium. The document provides technical information about the evaluation and uses of field-portable x-ray fluorescence technologies to assess and characterize such soils.

Characterization Protocol for Radioactive Contaminated Soils (PB92-963354).

The fact sheet describes physical separation technologies that may be useful in characterizing

sites at which soils are contaminated with radioactive wastes. It provides information about the use of physical separation technologies to reduce the volume of radioactive soil on site.

 Consortium for Site Characterization
Technology—Innovative Technology
Verification Reports (Fact Sheet EPA 542-F-96-012).

The Consortium for Site Characterization Technology (CSCT) is a partnership program involving EPA, the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE) that is responsible for evaluating and verifying the performance of innovative site characterization technologies. The CSCT provides technology support to technology developers, evaluates and verifies data generated during demonstrations, and develops and disseminates information about the performance of site characterization technologies. The fact sheet describes the mission of the Consortium and its activities and identifies points of contacts. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The Consortium is in the process of finalizing verification statements and accompanying reports for 12 technologies in three technology categories: Cone Penetrometer/Laser Induced Fluorescence (LIF), Field-Portable X-Ray Fluorescence (FPXRF), and Portable Gas Chromatograph/Mass Spectrometers (GC/MS). Innovative technology verification reports for two in situ laser-induced fluorescence-based technologies, Site Characterization and Analysis Penetrometer System (SCAPS) and the Rapid Optical Screening Tool (ROST), are now available. The reports listed below document the demonstration activities, and present and evaluate the demonstration data to verify the performance of the tested technologies relative to claims of the developers:

- Cone Penetrometer/Laser Induced Fluorescence (LIF)
 - Rapid Optical Screening Tool (ROST) (EPA 600-R-97-020)
 - Site Characterization and Analysis Penetrometer System (SCAPS) (EPA 600-R-97-019)
- Field-Portable X-Ray Fluorescence (FPXRF)
- Portable Gas Chromatograph/Mass Spectrometers (GC/MS)

Development of a Battery-Operated Portable Synchronous Luminescence Spectrofluorometer (PB94-170032).

The document describes a field screening method that may be useful in characterizing sites at which contaminated groundwater or hazardous waste is present. Battery-operated portable synchronous luminescence spectrofluorometers are used to conduct trace analyses of such contaminants as polynuclear aromatic hydrocarbons (PAH), creosote, and polychlorinated biphenyls (PCB) in complex mixtures. The report describes the components of the instrument and provides an evaluation of its effectiveness when used to analyze soil samples.

DNAPL Site Evaluation (PB93-150217).

The manual provides information about the treatment of sites contaminated with dense nonaqueous phase liquids (DNAPL), particularly chlorinated solvents. It discusses several issues related to the characterization of such sites, including the risk of inducing migration of DNAPLs by drilling, pumping, or conducting other field activities; the use of special sampling and measurement methods to assess the presence and migration potential of DNAPLs; the development of cost-effective characterization strategies that account for chemical transport processes of DNAPLs; and the collection of data required to select and implement a remedy. The manual also describes and evaluates activities that can be used to determine the presence and fate and transport of subsurface DNAPL contamination.

Navy/EPA Technical Screening Matrix.

The U.S. Navy and EPA currently are developing a site characterization screening matrix and reference guide that is intended to provide users with an understanding of the site characterization technology options available to them and the applicability of various technologies to their particular problem(s). The matrix will provide a general understanding of state-of-the-art technologies for site characterization. When completed, the matrix and reference guide will enhance technology information transfer and provide much-needed comparison among competing technologies. The document will be available in September 1997.

Sampling of Contaminated Sites (PB92-110436).

The paper discusses the development of sampling plans to identify and characterize contaminants that may exist at a site. It describes the components of a sampling plan and identifies issues that should not be overlooked during the sampling of contaminants.

**Superfund Innovative Technology Evaluation (SITE) Program—Measuring and Monitoring Program Reports.**

An extensive inventory of reports of the evaluation of measurement and monitoring technologies in the SITE program is available to assist decision makers in reviewing technology options and assessing a technology's applicability to a particular site. The reports evaluate all information about a technology; provide an analysis of its overall applicability to site characteristics, waste types, and waste matrices; and present testing procedures, performance and cost data, and QA/QC standards. The Demonstration Bulletins provide summarized descriptions of technologies and announcements of demonstrations. The Innovative Technology Evaluation Reports provide full reports of the demonstration results, including technical data useful to decision makers. See page A-113 in *Appendix A, Brownfields Site Cleanup "Starter Kit,"* for a complete list of the reports and the publication numbers.

The reports provide information on the following technologies:

- Analytical Screening Methods
- Cone Penetrometer
- Immunoassay Test Kits

**Vendor Field Analytical and Characterization Technologies System (Vendor FACTS), Version 2.0.**

The Windows™-based system contains information provided by vendors on field-portable technologies for measuring and monitoring contaminated soil and groundwater. Some of the technologies listed in the system are air measurement technologies, analytical detectors, gas chromatography equipment, chemical reaction-based indicators, immunoassay instruments, and soil-gas analyzers. The system allows users to screen technologies by such parameters as contaminant, medium, or development status. Updated annually, the system can be downloaded from the Internet at <http://www.ttemi.com/vfacts> or from the CLU-IN Web site at <http://clu-in.com>

**Vendor FACTS Bulletin (EPA 542-N-97-007).**

The bulletin informs technology users of the composition of Vendor FACTS and technology vendors of the opportunities

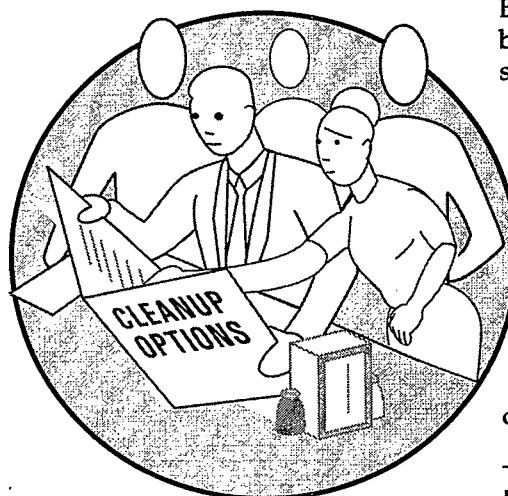
Vendor FACTS can offer them. The bulletin also provides information on obtaining copies of the software and user manual, and system requirements, as well as a registration and order form. A list of the names of vendors, the types of technology used, and the contaminants monitored also is provided. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



A copy of the Vendor FACTS Bulletin is provided on page A-115 in *Appendix A, Brownfields Site Cleanup "Starter Kit,"*

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CLEANUP OPTIONS RESOURCES



Evaluate Applicable Cleanup Alternatives for the Site

The review and analysis of cleanup alternatives rely on the data collected during the site assessment and investigation phases which are discussed in the preceding sections of the Tool Kit. The purpose of screening various technologies is to evaluate those technologies for their capability to meet specific cleanup and redevelopment objectives. For Brownfields sites, it also is important to consider budget requirements and to maintain a work schedule so that the project remains profitable.

The role of institutional controls, such as zoning and deed restrictions, posting of safety signs, and efforts to increase community awareness of the environmental conditions and cleanup activities at the site, also is an important consideration during this phase.

The information resources listed below provide information about reviewing and analyzing cleanup options and technology alternatives.

Resources

A. General Technology Program Information



Listed below are resources that provide general information about the availability of technology resources and descriptions of EPA programs and initiatives on innovative technologies. Reports and literature on EPA guidance for conducting treatability studies, the EPA Superfund Innovative Technology Evaluation (SITE) program, and a bulletin board system designed for the exchange of information also are included.

- Clean-Up Information (CLU-IN) Bulletin Board System.
- The system is designed for use by hazardous waste cleanup professionals who need current information on innovative technologies for remediation and access to EPA publications, other regularly updated information, and databases. CLU-IN can be accessed by modem at (301) 589-8366 or through the Internet at <http://clu-in.com>. Assistance can be reached at (301) 589-8368.



A copy of the CLU-IN brochure is provided on page A-91 in *Appendix A, Brownfields Site Cleanup "Starter Kit."*



Clean-Up Information Home Page on the World Wide Web (EPA 542-F-96-011). The home page provides information about innovative treatment technologies to the hazardous waste remediation community. It describes programs, organizations, publications, and other tools for EPA and other Federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. The home page can be accessed at <http://clu-in.com>.

Conducting Treatability Studies Under RCRA (OSWER Directive 9380.3-09FS, PB92-963501). The fact sheet provides a quick reference on EPA's RCRA program and the opportunities to perform treatability studies of treatment technologies. It provides information about the treatability studies exemption rule, research development and demonstration permits, Subpart X permits, and corrective action. The fact sheet also lists the states that are authorized by EPA to issue treatability studies exemptions and research, development, and demonstrations permits under RCRA.

Superfund Innovative Technology Evaluation Program: Emerging Technology Program (EPA 540-F-95-502).

The SITE program encourages the development of innovative technologies for faster, more effective, and less costly treatment of hazardous waste. Through the program, EPA evaluates technologies in conjunction with technology developers to determine the effectiveness of each innovative technology in meeting performance and cost objectives. The SITE Program consists of the following four evaluation components: the Emerging Technology Program, the Demonstration Program, the Monitoring and Measurement Technologies Program, and Technology Transfer. The Emerging Technology Program provides direct technical and financial assistance to developers of innovative remediation technology.

The brochure provides information about the Emerging Technology Program, including its purpose, background, and components, as well as

the results of the program. The brochure also provides contact information.

Superfund Innovative Technology Evaluation Program: Fact Sheet (EPA 542-F-95-009).

The fact sheet provides information about the SITE program. The fact sheet, which describes efforts to advance the development, evaluation, and commercialization of innovative technologies used to assess and clean up hazardous waste sites, includes a description of the components of the program, as well as a summary of the benefits and stages of technology development. A list of documents available from EPA's National Risk Management Research Laboratory also is included. The fact sheet also provides information on obtaining copies of the documents and videotapes.

Technology Transfer Highlights (EPA 625-N-96-001).

The document identifies and describes information resources developed by EPA's Center for Environmental Research Information (CERI). CERI provides information about a broad range of technical options, and may at times highlight the development of new technologies. The document lists resources for manuals; technical capsule reports; seminar publications; brochures; handbooks; guides to pollution prevention; summary reports; environmental regulations and technical publications; and software. It also provides titles, document numbers, and ordering information.

B. Technology Survey Resources

The documents listed below provide general information about innovative technologies in the form of bibliographies, status reports, and case studies. Survey reports on the application of innovative treatment technologies to specific contaminants and site types as well as PC-based searchable database systems are included.

General

CLU-IN **Abstracts of Remediation Case Studies (EPA 542-R-95-001, PB95-201711).** The document is a collection of two-page abstracts summarizing 37 case studies of site remediation projects. It was prepared by member agencies of the Federal Remediation Technologies Roundtable. Each abstract contains information on the site,

contaminants and media treated, the technology used, and the technology vendor, as well as a summary of cost and performance data and a point of contact for the technology application. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



- **Accessing Federal Data Bases for Contaminated Site Clean-Up Technologies, Fourth Edition (EPA 542-B-95-005, PB96-141601).**

The document, prepared by the Federal Remediation Technologies Roundtable, provides information on accessing Federal databases that contain data on innovative remediation technologies. Each database profile contains data elements, system uses, and hardware and software requirements. The profiles also provide points of contact for each system. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Alternative Treatment Technology Information Center (ATTIC).

The Alternative Treatment Technology Information Center (ATTIC) is a comprehensive computer database system that provides up-to-date information on innovative treatment technologies. The database contains information on biological, chemical, and physical treatment processes; solidification and stabilization processes; and thermal treatment technologies. The on-line automated bibliographic reference integrates existing data on hazardous waste into a unified, searchable resource. The ATTIC system provides users with access to several independent databases, an electronic bulletin board system, a hotline, and a repository of documents related to alternative and innovative treatment technologies. The ATTIC database can be accessed by modem at (703) 908-2138. Assistance can be reached at (703) 908-2137.



- **Bibliography for Innovative Site Clean-Up Technologies (EPA 542-B-96-003).**

The document is a comprehensive guide to information resources available on innovative site cleanup technologies. The bibliography lists resources for technology survey reports; EPA program information; groundwater (*in situ*) treatment; thermal treatment; bioremediation; soil vapor extraction and enhancements; physical and chemical treatment; site characterization; other conferences and

international surveys; technical support; community relations; bulletin board systems, databases, software, and the Internet; technology newsletters; and innovative site remediation engineering technology monographs. The document also provides titles, document numbers, and ordering information. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>



- **Completed North American Innovative Technology Demonstration Projects (EPA 542-B-96-002, PB96-153127).**

The report summarizes more than 300 innovative technology field demonstration projects that have been completed in North America. The demonstration projects listed include those performed, co-sponsored, or funded through programs developed by EPA, the military services, the U.S. Department of Energy (DOE), the U.S. Department of Interior (DOI), the government of Canada, and the State of California. The report summarizes key information from available demonstration projects in a single document and presents that information in a manner that enables project managers and other interested persons to easily identify innovative technologies that may be appropriate to their particular site remediation needs. The report highlights key features of the demonstrations, including contaminants treated, site types, technology types, technology vendors, project sponsors, and technical reports available. The report can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



- **Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, Fifth Edition (EPA 542-B-95-004, PB96-145099).**

The document is a bibliography of EPA reports that describe Federal research, evaluation, and demonstration of innovative treatment technologies for hazardous waste sites. The bibliography lists EPA resources for international surveys and conferences; technology survey reports; treatability studies; groundwater treatment; thermal processes; biological, physical and chemical processes; and community relations. The document also provides titles, document numbers, and ordering information. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

Guide to Documenting Cost and Performance for Remediation Projects (EPA 542-B-95-002, PB95-182960).

The document is a guide that recommends the types of data that should be collected to document the performance and cost of future cleanups. The guide specifies data elements for 13 conventional and innovative cleanup technologies: soil bioventing, soil flushing, soil vapor extraction, groundwater sparging, in situ groundwater remediation, pump-and-treat technologies, composting, incineration, land treatment, slurry-phase soil bioremediation, soil washing, stabilization, and thermal desorption. The document provides site managers with a standard set of parameters for documenting completed remediation projects. A number of Federal agencies have made commitments to using the guidance to collect data for full-scale cleanups, demonstrations, and treatability studies. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

Innovative Treatment Technologies: Annual Status Report, Eighth Edition (EPA 542-R-96-010).

The report documents and analyzes the selection and use of innovative treatment technologies in the Superfund program and at some non-Superfund sites being addressed by the U.S. Department of Defense (DoD) and DOE. The report contains site-specific information on almost 400 projects at which soil vapor extraction, soil washing, bioremediation, solvent extraction, and other innovative technologies are in use. The seventh edition of the report can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

Innovative Treatment Technologies: Annual Status Report Database (ITT Database).

The Windows™-based system contains information on the almost 400 sites documented in the eighth edition of the Annual Status Report. The database provides information about site type, technology selected or used, target contaminants and matrix, and status of the project, as well as contact names and telephone numbers. The database is searchable and can generate reports. The database can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

Remediation Case Studies: Fact Sheet and Order Form (EPA 542-F-95-003).

The fact sheet provides information about the contents of 37 case study reports on full-scale remediation and demonstration projects prepared by the member agencies of the Federal Remediation Technologies Roundtable, the Abstracts of Remediation Case Studies, and the Guide to Documenting Cost and Performance for Remediation Projects. The case studies describe aboveground and in situ technologies, including bioremediation, groundwater treatment, soil vapor extraction, thermal desorption, soil washing, and in situ vitrification. Each case study documents project design, operation, performance, costs, and lessons learned. A summary of the case studies is included in the fact sheet and order form. The order form provides information about obtaining copies of the documents. The fact sheet and order form can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

Remediation Technologies Screening Matrix and Reference Guide, Second Edition (EPA 542-B-94-013, PB95-104782; Fact Sheet EPA 542-F-95-002).

The document is designed to help site remediation project managers narrow the field of remediation alternatives and identify potentially applicable technologies for more detailed assessment and evaluation before remedy selection. The document summarizes the strengths and weaknesses of 55 innovative and conventional technologies for remediation of soils, sediments, sludges, groundwater, and air emissions and off-gases. Treatment, containment, separation of wastes, and enhanced recovery technologies are covered. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The fact sheet provides the table of contents of the matrix and reference guide and information on obtaining a copy of the document.



A copy of the screening matrix is provided on page A-93 in *Appendix A, Brownfields Site Cleanup "Starter Kit."*

Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources (EPA 542-B-95-001).

The document is a bibliography of reports that describe selected alternative and innovative treatment technologies for corrective action and site remediation. The bibliography lists resources for such topics as treatability studies, groundwater, thermal treatment, bioremediation, soil vapor extraction and enhancements, soil washing treatment, physical and chemical treatments, technical support, and community relations. It also lists conferences and international surveys, technology survey reports and guidance, bulletin board systems and databases, technology newsletters, publications of the Federal Remediation Technologies Roundtable, and innovative site remediation technology monographs. The document provides titles, document numbers, and ordering information.

Superfund Innovative Technology Evaluation Program: Technology Profiles, Ninth Edition (EPA 540-R-97-502).

The document provides profiles of more than 150 demonstration, emerging, and monitoring and measurement technologies currently being evaluated. Each technology profile identifies the developer and process name of the technology, describes the technology, discusses its applicability to waste, and provides a project status report and contact information. The profiles also include summaries of demonstration results, if available. The document can be downloaded free of charge from the SITE Web site at <http://www.epa.gov/ord/site/>.

 **Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition (EPA 542-B-93-009, PB94-144565).**

The document is a compilation of abstracts that describe field demonstrations of innovative technologies that treat hazardous waste at contaminated sites. The abstracts are information resources that hazardous waste site project managers can use to assess the availability and practicability of innovative technologies for treating contaminated groundwater, soils, and sludge. The document describes more than 110 demonstrations, sponsored by Federal agencies, in six different technology categories, involving the use of

innovative technologies to treat soil and groundwater. A matrix that lists the demonstration categories, the type of contaminant, media that can be treated, and the treatment setting for each innovative technology demonstrated also is provided in the document. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Technology Preselection Data Requirements: Engineering Bulletin (EPA 540-S-92-009).

The document, prepared by EPA's National Risk Management Research Laboratory, provides a listing of soil, water, and contaminant data elements needed to evaluate the potential applicability of technologies for treating contaminated soil and water. The bulletin identifies physical and chemical site characteristics for which observations and measurements should be compiled. The summary is designed to help remedial project managers and other site cleanup managers understand and select technologies that may have potential applicability to their particular site.

 **Vendor Information System for Innovative Treatment Technologies (VISITT), Version 5.0.**

The PC-based system contains information about 325 innovative remediation technologies (70 percent of which are commercially available) offered by 204 vendors. The major technology categories are acid and solvent extraction, bioremediation, chemical treatment, in situ thermally enhanced recovery, soil vapor extraction, soil washing, thermal desorption, and vitrification. VISITT provides detailed information that enables users to screen and assess remediation technologies quickly. Users also can build queries that reflect the conditions at a particular site. The system is available on diskette, with a user manual, and requires a personal computer with DOS Version 3.3 or higher, 640K of RAM, and 10MB hard disk space. It is updated annually and can be downloaded from the Internet at <http://www.ttemi.com/visitt> or from the CLU-IN Web site at <http://clu-in.com>.

 **VISITT 5.0 Bulletin (EPA 542-N-96-006).**

The bulletin informs remediation professionals of the composition of VISITT and innovative treatment technology vendors of the opportunities VISITT can offer them. The bulletin also provides information on obtaining

copies of the software and user manual, system requirements, and registration as well as an order form. A list of vendors also is provided. A copy of the VISITT Bulletin is provided on page A-123 in *Appendix A, Brownfields Site Cleanup "Starter Kit."*

Site/Waste Types

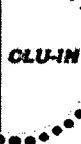
METALS

In Situ Treatment of Metal-Contaminated Soils (EPA 542-R-96-001).

The document provides information about four in situ technologies for treating metal-contaminated soils: electrokinetic remediation, phytoremediation, soil flushing, and solidification/stabilization. The report is intended to assist in screening new technologies early in the remedy evaluation and selection process. It identifies vendors, summarizes performance data, and discusses technology attributes that should be considered during the early screening of potential remedies for metal-contaminated soils. The document outlines the relatively few alternative methods for in situ treatment of metals.

Literature Review Summary of Metals Extraction Processes Used to Remove Lead From Soils: Project Summary (EPA 600-SR-94-006).

The document reviews and evaluates literature about metals extraction technologies, soil characterization, chelating agents, and membranes. The literature assessment provides information about potential operating problems that can be identified and avoided when extraction processes are used to recover lead from soils.

CLU-IN  **Recent Developments for In Situ Treatment of Metal-Contaminated Soils (EPA 542-R-97-004).**

The document provides hazardous waste cleanup professionals with an update on the status of four available and promising technologies—electrokinetics, phytoremediation, soil flushing, and solidification and stabilization—for in situ remediation of soil contaminated with heavy metals. The report is intended to assist in screening new technologies early in the remedy evaluation and selection process. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Selection of Control Technologies for Remediation of Lead Battery Recycling Sites: Engineering Bulletin (EPA 540-S-92-011, PB93-121333).

The document provides information about the selection of treatment technologies at lead battery recycling sites. It also describes treatability studies at lead battery recycling sites and discusses innovative technologies with the potential to treat lead-contaminated wastes.

POLYCHLORINATED BIPHENYLS (PCB)

Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment (EPA 540-S-93-506).

The document is intended to familiarize on-scene coordinators and remediation project managers with issues important to the successful selection of technology alternatives available for the remediation of soil and sediment contaminated with polychlorinated biphenyls (PCB) at Superfund sites.

UNDERGROUND STORAGE TANKS

How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites: A Guide for State Regulators (EPA 510-F-96-001; Fact Sheet EPA 510-F-96-005).

The guide provides information to help underground storage tank (UST) regulators understand the portion of a UST corrective action plan that proposes free product recovery techniques. The guide focuses on appropriate technology use, taking into consideration site-specific conditions. It also discusses the relevant properties of hydrocarbons and geologic media for free product recovery and the methods used to estimate the extent and volume of free product, as well as free product recovery technologies, mechanical components, operation, and monitoring requirements.

The fact sheet provides information on the organization of the guide, and how to obtain copies of the guide.

How To Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers (EPA 510-B-94-003, S/N 055-000-00499-4; Pamphlet EPA 510-F-95-003).

The guide was developed to assist state regulators in efficiently and confidently evaluating corrective

action plans (CAP) that incorporate alternative technologies. The guide, written in nontechnical language, takes the reader through the steps involved in reviewing a CAP. Each chapter presents a comprehensive description of the technology, an explanation of how it works, and a flow chart that illustrates the decision points in the process; information that will help the regulator evaluate whether a given technology will clean up a given site successfully; discussion and instruction to help the regulator evaluate whether a CAP is technically sound; a check list to assist the regulator in determining whether or not the CAP includes all the steps necessary; and a list of references.

The pamphlet provides information about the purpose, background, organization, and format of the guide. The pamphlet also provides instructions for ordering the guide.

Introducing TANK RACER (EPA 510-F-96-001). TANK RACER is a Windows™-based PC software that provides fast, accurate, and comprehensive cost estimates for cleanups at leaking UST sites. The software estimates costs for cleanups on a site-specific basis for all phases of remediation, including site assessment, remedial design, remedial action, operations and maintenance, tank closure, and site work and utilities, as well as the costs of using alternative technologies, such as air sparging, bioremediation, bioventing, groundwater extraction wells, land farming, natural attenuation, soil vapor extraction, and thermal desorption. The software was developed under an interagency agreement between the U.S. Air Force and EPA.

The pamphlet provides information about the software. The pamphlet also provides information about available training workshops.

Overview of UST Remediation Options (EPA 510-F-93-029).

The document is a collection of two-page fact sheets summarizing different options for remediating contamination from leaking underground storage tanks. Each fact sheet contains information on the option, advantages and limitations, system components, waste stream treatment, parameters to be monitored, cleanup levels, and time needed to achieve cleanup, as well as a summary of cost data.

WOOD PRESERVING/TREATMENT

Superfund Innovative Technology Evaluation Program: Technology Profiles, Ninth Edition (EPA 540-R-97-502).

The document provides profiles of more than 150 demonstration, emerging, and monitoring and measurement technologies currently being evaluated. Each technology profile identifies the developer and process name of the technology, describes the technology, discusses its applicability to waste, and provides a project status report and contact information. The profiles also include summaries of demonstration results, if available. The document can be downloaded free of charge from the SITE Web site at <http://www.epa.gov/ord/site/>.

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews. PC-based searchable databases also are included

Community Outreach

 **Citizens's Guides to Understanding Innovative Treatment Technologies.** The guides are prepared by EPA to provide site managers with nontechnical outreach materials, in English and Spanish, that they can share with communities in the vicinity of a site. The guides present information on innovative treatment technologies that have been selected or applied at some cleanup sites, provide overviews of innovative treatment technologies, and present success stories about sites at which innovative treatment technologies have been applied. The second document number listed after each title below is the document number for the guide in Spanish. The documents, including the Spanish versions, can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The guides contain information on the following subjects:

- *Bioremediation*
(EPA 542-F-96-007, EPA 542-F-96-023)
- *Chemical Dehalogenation*
(EPA 542-F-96-004, EPA 542-F-96-020)

- *In Situ Soil Flushing*
(EPA 542-F-96-006, EPA 542-F-96-022)
- *Innovative Treatment Technologies for Contaminated Soils, Sludges, Sediments, and Debris*
(EPA 542-F-96-001, EPA 542-F-96-017)
- *Natural Attenuation*
(EPA 542-F-96-015, EPA 542-F-96-026)
- *Phytoremediation*
(EPA 542-F-96-014, EPA 542-F-96-025)
- *Soil Vapor Extraction and Air Sparging*
(EPA 542-F-96-008, EPA 542-F-96-024)
- *Soil Washing*
(EPA 542-F-96-002, EPA 542-F-96-018)
- *Solvent Extraction*
(EPA 542-F-96-003, EPA 542-F-96-019)
- *Thermal Desorption*
(EPA 542-F-96-005, EPA 542-F-96-021)
- *Treatment Walls*
(EPA 542-F-96-016, EPA 542-F-96-027)

 Copies of the Citizen's Guides are provided in *Appendix A, Brownfields Site Cleanup "Starter Kit,"* beginning on page A-3.

Superfund Innovative Technology Evaluation (SITE) Program

SITE Program—Demonstration Program Reports.

An extensive inventory of reports of the evaluation of demonstration, emerging, and monitoring and measurement technologies in the SITE program is available to assist decision makers in reviewing technology options and assessing a technology's applicability to a particular site. The reports evaluate all information about a technology; provide an analysis of its overall applicability to site characteristics, waste types, and waste matrices; and present testing procedures, performance and cost data, and quality assurance and quality control standards. Applications Analysis Reports provide assessments of the applicability of technologies to a variety of sites and include cost and performance data. The Innovative Technology Evaluation Reports provide full reports of the demonstration results, including technical data useful to decision makers. See page A-105 in *Appendix A, Brownfields Site Cleanup "Starter Kit,"* for a complete list of the reports and the publication numbers.

The reports provide information on the following technologies:

- *Bioremediation/Biological Treatment*
- *Chemical-Volume Reduction*
- *Filtration Technologies*
- *Fracturing Technologies*
- *Oxidation*
- *Physical/Chemical*
- *Radio Frequency Heating*
- *Soil and Sediment Washing*
- *Solidification-Stabilization*
- *Solvent-Chemical Extraction*
- *Steam Stripping*
- *Thermal Treatment*
- *Vacuum Extraction*
- *Vitrification*

SITE Program—Measuring and Monitoring Program Reports.

An extensive inventory of reports of the evaluation of measurement and monitoring technologies in the SITE program is available to assist decision makers in reviewing technology options and assessing a technology's applicability to a particular site. The reports evaluate all information about a technology; provide an analysis of its overall applicability to site characteristics, waste types, and waste matrices; and present testing procedures, performance and cost data, and QA/QC standards. The Demonstration Bulletins provide summarized descriptions of technologies and announcements of demonstrations. The Innovative Technology Evaluation Reports provide full reports of the demonstration results, including technical data useful to decision makers. See page A-113 in *Appendix A, Brownfields Site Cleanup "Starter Kit,"* for a complete list of the reports and the publication numbers.

The reports provide information on the following technologies:

- *Analytical Screening Methods*
- *Cone Penetrometer*
- *Immunoassay Test Kits*

Bioremediation



- Bioremediation Field Evaluation:
Champion International Superfund Site,
Libby, Montana (EPA 540-R-96-500).

The Champion International Superfund site is a wood preserving facility that contaminated soil and groundwater with two wood preservatives: pentachlorophenol (PCP) and polynuclear aromatic hydrocarbons (PAH). The report provides the results of a field evaluation of three treatment processes—surface soil bioremediation, aboveground fixed-film bioreactor remediation, and *in situ* bioremediation—for the degradation of PCP and PAHs in soil and groundwater. The profile identifies the processes used to evaluate the technologies, and identifies points of contact. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



- Bioremediation Field Evaluation:
Eielson Air Force Base, Alaska
(EPA 540-R-95-533).
- Eielson Air Force Base is a site contaminated with jet fuel (petroleum hydrocarbons) in shallow unsaturated soil. The profile provides the results of a field evaluation of the use of soil-warming technologies to enhance the effectiveness of bioventing jet fuel-contaminated soil in a cold climate. Points of contact also are identified. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



- Bioremediation Field Initiative Site Profiles.
- The site profiles provide information on the status of bioremediation projects at sites at which field performance evaluations have been or are being conducted. The contaminants at the sites include benzene, toluene, ethylbenzene, and xylene (BTEX); creosote; pentachlorophenols (PCP); petroleum hydrocarbons; and polynuclear aromatic hydrocarbons (PAH). Each profile identifies the processes used to evaluate the technologies. Points of contact also are identified. The site profiles listed below can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>:

- *Libby Groundwater Superfund Site, Montana (EPA 540-F-95-506A)*
- *Eielson Air Force Base, Alaska (EPA 540-F-95-506B)*
- *Escambia Wood Preserving Site, Florida (EPA 540-F-95-506G)*
- *Hill Air Force Base Superfund Site, Utah (EPA 540-F-95-506C)*
- *Public Service Company of Colorado, Colorado (EPA 540-F-95-506D)*
- *Reilly Tar and Chemical Corporation, Minnesota (EPA 540-F-95-506H)*



- Bioremediation in the Field Search System (EPA 540-F-95-507; Fact Sheet EPA 540-F-94-506).

The system is a PC-based searchable database of information about sites at which bioremediation is being tested or implemented or at which cleanup by bioremediation has been completed. The database contains data on location, media, contaminants, technology, cost, and performance. The system can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The fact sheet provides information on the type of system, the type of information contained in the database, how the system works, how to obtain a copy of the system, and how to contribute to the database.



- Bioremediation Resource Guide (EPA 542-B-93-004, PB94-112307).
- The document aids decision makers in reviewing the applicability of bioremediation. The document also provides access information on electronic resources and hotlines; cites relevant Federal regulations; and provides abstracts of pertinent print resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Included is a bioremediation resource matrix that compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

EPA Engineering Bulletins.

The bulletins, developed by EPA's National Risk Management Research Laboratory, are a series of documents that summarize the latest information on specific treatment and remediation processes. The documents also provide information on the limitations of the technologies, the latest performance data, site requirements, and the status of the technologies. Sources for additional information also are identified. The bulletins provide detailed information about bioremediation technologies, including:

- *Composting: Engineering Bulletin (EPA 540-S-96-502)*
- *In Situ Biodegradation Treatment: Engineering Bulletin (EPA 540-S-94-502, PB94-190469)*
- *Rotating Biological Contactors: Engineering Bulletin (EPA 540-S-92-007)*
- *Slurry Biodegradation: Engineering Bulletin (EPA 540-2-90-016, PB91-228049)*

In Situ Bioremediation of Contaminated Ground Water (EPA 540-S-92-003, PB92-224336).

The document provides an overview of the factors involved in in situ bioremediation and outlines types of information required for the application of this technology. The document also identifies the advantages and disadvantages offered by the technology.

In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies (EPA 600-SR-93-124, PB93-215564).

The report provides information about the processes of soil and groundwater remediation and the technologies that can be used for in situ bioremediation of soil and groundwater. The document also reviews the applications and limitations of several technologies.

Remediation Case Studies: Bioremediation (EPA 542-R-95-002, PB95-182911).

Developed by EPA, DoD, and DOE, the case studies present cost and performance information for nine bioremediation projects, including bioventing and land treatment technologies, as well as a large-scale slurry-phase project. The most frequent contaminants of the projects are petroleum hydrocarbons, and two land treatment projects are completed cleanups at sites contaminated with creosote. The study is intended to

assist remedy selection at contaminated sites and to allow comparisons of bioremediation technologies. The document provides information about the sites, contaminants, and media treated, technologies, technology vendors, and a summary of cost and performance data. Points of contact also are identified. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Groundwater Treatment**Emerging Abiotic In Situ Remediation**

Technologies for Ground Water and Soil: Summary Report (EPA 542-S-95-001, PB95-239299). The document summarizes the status and trends in the development of abiotic technologies that treat contaminated groundwater in place or increase solubility and mobility of contaminants to improve their removal by pumping. The document provides an overview of site status reports that document demonstrations and research on emerging abiotic technologies: surfactant enhancements, treatment walls, hydraulic fracturing and pneumatic fracturing, cosolvents, electrokinetics, and thermal enhancements. The information provided in the report will allow site managers to understand the current investments in emerging abiotic technologies and make more informed decisions about their use for remediation.

Evaluation of Technologies for In Situ Cleanup of DNAPL Contaminated Sites (EPA 600-R-94-120, PB94-195039).

The document provides a review and technical evaluation of in situ technologies for the remediation of DNAPL contamination that has occurred below the groundwater tables. It reviews several in situ technologies and provides information about the evaluation of the technologies on the basis of theoretical background, field implementation, level of demonstration and performance, waste, technical and site applicability and limitations, and cost and availability.

Ground-Water Remediation Technologies Analysis Center.

The Ground-Water Remediation Technologies Analysis Center (GWRTAC) was established through a cooperative agreement between the National Environmental Technology Applications Center (NETAC) of the Center for Hazardous Materials Research (CHMR) and EPA. The goal of GWRTAC is to compile, analyze, and disseminate

information on innovative groundwater remediation technologies to industry, the research community, contractors, government, investors, and the public. The center currently is compiling information to be included in databases of interactive case studies and vendor information that will be available on the GWRTAC Web site. Additional information is available on the GWRTAC Web site at <http://www.gwrtac.org>.

-  **Ground-Water Treatment Technology Resource Guide (EPA 542-B-94-009, PB95-1398657).**
- The document aids decision makers in reviewing the applicability of groundwater treatment technologies. The document also provides access information on electronic resources and hotlines; cites relevant Federal regulations; and provides abstracts of pertinent print resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Included is a groundwater treatment technology resource matrix that compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

In Situ Bioremediation of Contaminated Ground Water (EPA 540-S-92-003, PB92-224336).

The document provides an overview of the factors involved in in situ bioremediation and outlines types of information required for the application of this technology. The document also identifies the advantages and disadvantages offered by the technology.

In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies (EPA 600-SR-93-124, PB93-215564).

The report provides information about the processes of soil and groundwater remediation and the technologies that can be used for in situ bioremediation of soil and groundwater. The document also reviews the applications and limitations of several technologies.

Light Nonaqueous Phase Liquids (EPA 540-S-95-500, PB95-267738).

The document provides information on the

transport, fate, characterization, and remediation of light nonaqueous phase liquids in the environment.

-  **Remediation Case Studies: Groundwater Treatment (EPA 542-R-95-003, PB95-182929).**
- Developed by EPA, DoD, and DOE, the report describes 11 groundwater treatment projects. Most of the projects address contaminants such as petroleum hydrocarbons and trichloroethylene (TCE). Eight of the projects are using pump-and-treat technologies, while two of the three completed projects utilized air sparging. The study is intended to assist remedy selection at contaminated sites and allow comparisons of groundwater treatment technologies. The document provides information about the sites, contaminants, and media treated, technologies, technology vendors, and a summary of cost and performance data. Points of contact also are identified. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

-  **Status Reports on In Situ Treatment Technology Demonstrations and Applications.**
- The series of seven documents describes more than 90 field demonstrations or full-scale applications of in situ abiotic technologies for treatment of nonaqueous phase liquids and groundwater. The documents, which can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>, provide information on the following subjects:

- *Altering Chemical Conditions (EPA 542-K-94-008)*
- *Cosolvents (EPA 542-K-94-006)*
- *Electrokinetics (EPA 542-K-94-007)*
- *Hydraulic and Pneumatic Fracturing (EPA 542-K-94-005)*
- *Surfactant Enhancements (EPA 542-K-94-003)*
- *Thermal Enhancements (EPA 542-K-94-009)*
- *Treatment Walls (EPA 542-K-94-004)*

Physical and Chemical Treatment

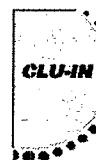
EPA Engineering Bulletins.

The bulletins, developed by EPA's National Risk Management Research Laboratory, are a series of

documents that summarize the latest information on specific treatment and remediation processes. Limitations of the technologies, the latest performance data, site requirements, and the status of the technologies also are summarized. The bulletins provide detailed information about several physical and chemical treatment processes, including:

- *Chemical Dehalogenation Treatment: APEG Treatment: Engineering Bulletin (EPA 540-2-90-015, PB91-228031)*
- *Chemical Oxidation Treatment: Engineering Bulletin (EPA 540-2-91-025, PB92-180066)*
- *In Situ Soil Flushing: Engineering Bulletin (EPA 540-2-91-021, PB95-180025)*
- *In Situ Vitrification Treatment: Engineering Bulletin (EPA 540-S-94-504, PB95-125499)*
- *Solidification/Stabilization of Organics and Inorganics: Engineering Bulletin (EPA 540-S-92-015)*
- *Supercritical Water Oxidation: Engineering Bulletin (EPA 540-S-92-006, PB92-224088)*

 Physical/Chemical Treatment Technology Resource Guide (EPA 542-B-94-008, PB95-138665).
The document aids decision makers in reviewing the applicability of physical/chemical treatment technologies. The document also provides access information on electronic resources and hotlines; cites relevant Federal regulations; and provides abstracts of pertinent print resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. The documents focus primarily on soil, sludge, and sediment and soil washing/flushing, solvent extraction, thermal desorption, and chemical dehalogenation. Included is a physical/chemical treatment technology resource matrix that identifies the technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification (EPA 542-R-95-005, PB95-182945).

Developed by EPA, DoD, and DOE, the case studies describe projects using thermal desorption, soil washing, and in situ vitrification technologies. Six of the projects were sites contaminated with polychlorinated biphenyls (PCB), pesticides, and trichloroethylene (TCE). The study is intended to assist remedy selection at contaminated sites and allow comparisons of technologies. Information about the sites, contaminants, and media treated, technologies, technology vendors, a summary of cost and performance data, and points of contact also are provided. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Soil Washing Treatment: Engineering Bulletin (EPA 540-2-90-017, PB91-228056).

The document provides detailed information about soil washing treatment processes. The limitations of the technologies and performance data as well as the status of the technologies also are described. The summary is designed to help remediation project managers and other site cleanup managers understand and select technologies that may have potential applicability to particular sites.

Solvent Extraction Treatment: Engineering Bulletin (EPA 540-S-94-503, PB94-190477).

The document aids decision makers in evaluating the potential applicability of solvent extraction treatment processes for treating contamination at a site. In addition, the bulletin also provides information on the limitations of the technology, the latest performance data, site requirements, the status of the technology, and identifies sources for more information.

Soil Vapor Extraction and Enhancements

EPA Engineering Bulletins.

The documents listed below provide information about several soil vapor extraction and enhancement technologies. Limitations of the technologies, the latest performance data, site requirements, and the status of the technologies also are summarized. The documents are designed to help remediation project managers and other site

cleanup managers understand and select technologies that may have potential applicability to particular sites. The bulletins provide detailed information about the following technologies:

- *In Situ Soil Vapor Extraction Treatment: Engineering Bulletin (EPA 540-2-91-006, PB91-228072)*
- *In Situ Steam Extraction Treatment: Engineering Bulletin (EPA 540-2-91-005, PB91-2228064)*



Remediation Case Studies: Soil Vapor Extraction (EPA 542-R-95-004, PB95-182937). Developed by EPA, DoD, and DOE, the report describes 10 projects. Eight of the projects were sites contaminated with various chlorinated aliphatic contaminants, such as trichloroethylene (TCE). The study is intended to assist remedy selection at contaminated sites and allow comparisons of soil vapor extraction technologies. Information about the site, contaminants, and media treated, technology, technology vendor, a summary of cost and performance data, and points of contact also are provided. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide: Air Sparging, Bioventing, Fracturing, and Thermal Enhancements (EPA 542-B95-003). The technology resource guide contains information on documents, databases, hotlines, and dockets pertaining to soil vapor extraction enhancement technologies. The document also identifies regulatory mechanisms that can ease implementation of the technology at hazardous waste sites. The guide contains a resource matrix that identifies the technology, medium, and contaminants covered in the document, and provides detailed information on how to obtain the publications listed. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.



Soil Vapor Extraction (SVE) Treatment Technology Resource Guide (EPA 542-B-94-007). The document aids decision makers in reviewing the applicability of soil vapor extraction treatment technologies. The document also provides access information on electronic resources and hotlines; cites relevant Federal regulations; and provides abstracts of pertinent print resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Included is a soil vapor extraction treatment technology resource matrix that compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Thermal Treatment

EPA Engineering Bulletins.

Developed by EPA's National Risk Management Research Laboratory, the bulletins are a series of documents that summarize the latest information on specific treatment and remediation processes. The bulletins provide site managers with an understanding of data and site characteristics necessary to evaluate the potential applicability of a technology to specific sites. The bulletins provide detailed information about soil treatment technologies, including:

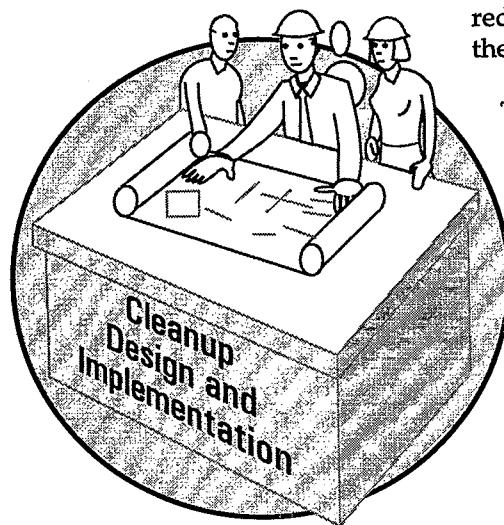
- *Mobile/Transportable Incineration Treatment: Engineering Bulletin (EPA 540-2-90-014, PB91-228023)*
- *Pyrolysis Treatment: Engineering Bulletin (EPA 540-S-92-010)*
- *Thermal Desorption Treatment: Engineering Bulletin (EPA 540-S-94-501, PB94-160603)*



Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification (EPA 542-R-95-005, PB95-182945).

Developed by EPA, DoD, and DOE, the case studies describe projects using thermal desorption, soil washing, and in situ vitrification technologies. Six of the projects were sites contaminated with polychlorinated biphenyls (PCB), pesticides, and trichloroethylene (TCE). The study is intended to assist remedy selection at contaminated sites and allow comparisons of technologies. Information about the sites, contaminants, and media treated, technologies, technology vendors, a summary of cost and performance data, and points of contact also are provided. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLEANUP DESIGN AND IMPLEMENTATION RESOURCES



Cleanup
Design and
Implementation

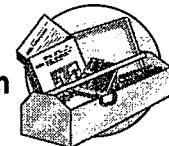
Develop and Carry Out Detailed Cleanup Plans for the Site

This phase focuses on the design and implementation of a cleanup plan to prepare the property for redevelopment and reuse. The design of the cleanup plan and implementation of the technology options selected in the previous phase involves close coordination with all other redevelopment efforts in the immediate vicinity of the site.

The information resources described below provide information about developing and implementing cleanup plans.

Resources

A. General Technology Program Information



Listed below are resources that provide general information about the availability of technology resources and descriptions of EPA programs and initiatives on innovative technologies. Reports and literature on EPA guidance for conducting treatability studies, the EPA Superfund Innovative Technology Evaluation (SITE) program, and a bulletin board system designed for the exchange of information also are included.



- Initiatives to Promote Innovative Technology in Waste Management Programs (OSWER Directive 9380.0-25, EPA 540-F-96-012).

The policy directive, issued April 29, 1996, describes several initiatives to facilitate the testing, demonstration, and use of innovative cleanup and field measurement technologies and stresses EPA's commitment to promoting the development and commercialization of environmental technologies. The initiatives under the directive place a high priority on selecting innovative treatment and characterization technologies, reducing impediments to the development and use of innovative technologies, and sharing the risks of using innovative treatment technologies. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

CLU-IN

State Policies Concerning the Use of Injectants for In Situ Ground Water Remediation (EPA 542-R-96-001, PB96-164538).

The report identifies specific state regulatory and policy barriers to the use of techniques that enhance in situ groundwater treatment technologies through the subsurface injection of surfactants, cosolvents, and nutrients. The report also describes the experiences and policies of each state and provides contact information for obtaining additional assistance. The document can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

B. Technology Survey Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies and status reports. A bulletin board system designed for the exchange of information also is included.

CLU-IN

Vendor Information System for Innovative Treatment Technologies (VISITT), Version 5.0.

The PC-based system contains information about 325 innovative remediation technologies (70 percent of which are commercially available) offered by 204 vendors. The major technology categories are acid and solvent extraction; bioremediation; chemical treatment; in situ thermally enhanced recovery; soil vapor extraction; soil washing; thermal desorption; and vitrification. VISITT provides detailed information that enables users to screen and assess remediation technologies quickly. Users also can build queries that reflect the conditions at a particular site. The system is available on diskette, with a user manual, and requires a personal computer with DOS Version 3.3 or higher, 640K of RAM, and 10MB hard disk space. It is updated annually and can be downloaded from the Internet at <http://www.ttemi.com/visitt> or from the CLU-IN Web site at <http://clu-in.com>.

 **VISITT 5.0 Bulletin (EPA 542-N-96-006).**
The bulletin informs remediation professionals of the composition of VISITT and innovative treatment technology vendors of the opportunities VISITT can offer them. The bulletin also provides information on obtaining copies of the software and user manual, system

requirements, and registration as well as an order form. A list of vendors also is provided. A copy of the VISITT Bulletin is provided on page A-123 in Appendix A, Brownfields Site Cleanup "Starter Kit."

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews. PC-based searchable databases also are included.

CLU-IN

Citizens's Guides to Understanding Innovative Treatment Technologies.

The guides are prepared by EPA to provide site managers with nontechnical outreach materials, in English and Spanish, that they can share with communities in the vicinity of a site. The guides present information on innovative treatment technologies that have been selected or applied at some cleanup sites, provide overviews of innovative treatment technologies, and present success stories about sites at which innovative treatment technologies have been applied. The second document number listed after each title below is the document number for the guide in Spanish. The documents, including the Spanish versions, can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

The guides contain information on the following subjects:

- *Bioremediation*
(EPA 542-F-96-007, EPA 542-F-96-023)
- *Chemical Dehalogenation*
(EPA 542-F-96-004, EPA 542-F-96-020)
- *In Situ Soil Flushing*
(EPA 542-F-96-006, EPA 542-F-96-022)
- *Innovative Treatment Technologies for Contaminated Soils, Sludges, Sediments, and Debris*
(EPA 542-F-96-001, EPA 542-F-96-017)
- *Natural Attenuation*
(EPA 542-F-96-015, EPA 542-F-96-026)
- *Phytoremediation*
(EPA 542-F-96-014, EPA 542-F-96-025)
- *Soil Vapor Extraction and Air Sparging*
(EPA 542-F-96-008, EPA 542-F-96-024)

- *Soil Washing*
(EPA 542-F-96-002, EPA 542-F-96-018)
- *Solvent Extraction*
(EPA 542-F-96-003, EPA 542-F-96-019)
- *Thermal Desorption*
(EPA 542-F-96-005, EPA 542-F-96-021)
- *Treatment Walls*
(EPA 542-F-96-016, EPA 542-F-96-027)



Copies of the Citizen's Guides are provided in *Appendix A, Brownfields Site Cleanup "Starter Kit,"* beginning on page A-3.



Technology Resource Guides. The five technology resource guides contain information on documents, databases, hotlines, and dockets pertaining to the subject technology. They also identify regulatory mechanisms that can ease implementation of the technology at hazardous waste sites. Each guide contains a resource matrix that identifies the technology, medium, and contaminants covered in each document. The guides can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

- *Bioremediation Resource Guide*
(EPA 542-B-93-004, PB94-112307)
- *Ground-Water Treatment Technology Resource Guide* (EPA 542-B-94-009, PB95-138657)
- *Physical/Chemical Treatment Technology Resource Guide* (EPA 542-B-94-008, PB95-138665)
- *Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide: Air Sparging, Bioventing, Fracturing, and Thermal Enhancements* (EPA 542-B-95-003)
- *Soil Vapor Extraction (SVE) Treatment Technology Resource Guide* (EPA 542-B-94-007)

WASTECH® Series of Innovative Site Remediation Technology Engineering Monographs.

The WASTECH® project generates authoritative, consensus-based engineering monographs for remediation of hazardous waste sites and contaminated soils and groundwater. WASTECH® is funded by EPA, DoD, DOE, and the American Academy of Environmental Engineers®. The project originated primarily from the substantial expenditures EPA has made and continues to make

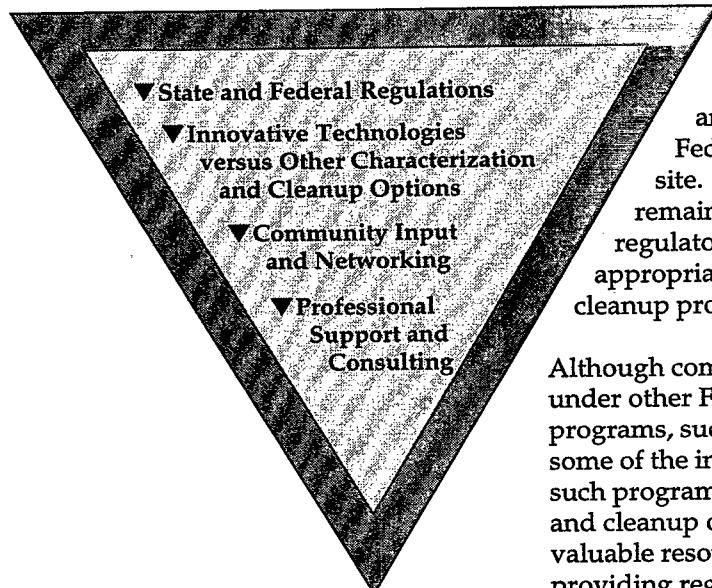
in the quest to foster the use of those technologies which may offer improved performance and cost savings over traditional methods. During Phase I of the project, eight monographs were published in 1994 and 1995 covering the basics of these technologies, i.e., identification and description, potential applications, process evaluations, and limitations. During 1997 and early 1998, an additional seven volumes covering the design and applications, including actual case studies, will be produced. The eight volumes of Phase I currently are available. The Phase II monographs covering the design and applications will be available in the fall of 1997. Copies of the individual monographs (by technology type) or the entire series may be purchased by contacting the American Academy of Environmental Engineers® by telephone at (410) 266-3390 or by facsimile at (410) 266-7653.

An order form is provided in *Appendix D, How to Order Documents.* The volumes contain information on the following technologies:

- *Bioremediation*
- *Chemical Treatment*
- *Soil Washing/Soil Flushing*
- *Solidification/Stabilization*
- *Solvent/Chemical Extraction*
- *Thermal Desorption*
- *Thermal Destruction*
- *Vacuum Vapor Extraction*

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OTHER IMPORTANT CONSIDERATIONS AND RESOURCES



Understanding Regulatory Guidelines and Regulations

Understanding the applicable regulatory guidelines and regulations is crucial to selecting the appropriate technologies for cleaning up a Brownfields site. It is important to note that many Brownfields sites will be managed under state regulatory authorities.

Therefore, the state regulatory authority will specify many of the requirements for, and steps in, site assessment, site investigation, the selection of cleanup options, and the design and implementation of cleanup. State regulatory agencies should be

consulted to determine what, if any, site-specific requirements may exist. State regulators also can help to identify other regulatory guidelines and regulations (such as applicable Federal statutes) that also may affect the site. For these reasons, it is important to remain in constant contact with state regulatory agencies, as well as any other appropriate regulatory agencies, throughout the cleanup process.

Although compliance with official policy directives under other Federal regulatory and cleanup programs, such as Superfund, may not be required, some of the information and lessons learned under such programs may be useful in the investigation and cleanup of Brownfields sites. EPA also can be a valuable resource for Brownfields stakeholders by providing regulatory and policy support to facilitate the selection of technologies. Other guidance and standards are promulgated by government and nongovernment organizations, such as the Federal Deposit Insurance Corporation (FDIC), the Small Business Administration (SBA), and the American Society for Testing and Materials (ASTM). The box on the next page provides descriptions of the various EPA hotlines for statutory and regulatory programs.

HOTLINES AND OTHER SERVICES

Center for Environmental Research Information (CERI).

CERI is the focal point for the exchange of scientific and technical environmental information produced by EPA. CERI publishes brochures, capsule and summary reports, handbooks, newsletters, project reports, and manuals. The center operates daily, Monday through Friday, 8:00 a.m. to 4:30 p.m. eastern standard time (EST). The center can be reached by telephone at 513-569-7391.

Resource Conservation and Recovery Act/Underground Storage Tanks (RCRA/UST), Superfund, and Emergency Planning and Community Right-to-Know Act (EPCRA) Hotline.

This hotline provides information about the RCRA/UST, Superfund, and EPCRA programs. The hotline handles information about EPA's RCRA regulations and programs implemented under RCRA, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPCRA, and the Superfund Amendments and Reauthorization Act (SARA) Title III. The hotline also provides referrals for obtaining related documents concerning the RCRA, UST, Superfund /CERCLA, and Pollution Prevention/Waste Minimization programs. Translation is available for Spanish speaking callers. The hotline operates daily Monday through Friday, 9:00 a.m. to 6:00 p.m. EST. The hotline can be reached by telephone at 800-424-9346 for all nongovernment locations outside the Washington, DC metropolitan local calling area, or 703-412-9810 for all locations in the Washington, DC metropolitan local calling area.

RCRA Docket and Information Center (RIC).

The RIC provides public access to all regulatory materials supporting EPA's actions under RCRA and disseminates publications from EPA's Office of Solid Waste and Emergency Response (OSWER). The information center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The information center can be reached by telephone at 703-603-9230.

Superfund Docket and Information Center.

The Superfund Docket and Information Center provides access to Superfund regulatory documents, Superfund Federal Register Notices, and Records of Decision (ROD). The center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The center can be reached by telephone at 703-603-8917 or by facsimile at 703-603-9133.

TechDirect.

TechDirect is a free electronic mail service that highlights new publications and events of interest to site cleanup professionals. Approximately once a month, EPA's Technology Innovation Office (TIO) sends subscribers an e-mail message announcing the availability of publications and the scheduling of events. The message also directs subscribers to sources from which they can obtain more information. Contact Mr. Jeff Heimerman at 703-603-7191 or by e-mail at heimerman.jeff@epamail.epa.gov for more information.

Toxic Substances Control Act (TSCA) Assistance Information Service.

The information service provides information about regulations under TSCA to the chemical industry, labor and trade organizations, environmental groups, and the general public. Technical as well as general information is available. The information service operates daily, Monday through Friday, 8:30 a.m. to 5:00 p.m. EST. The information service can be reached by telephone at 202-554-1404.

Comparing Innovative Technologies to Other Characterization and Cleanup Options

The Tool Kit and Road Map focus on innovative characterization and treatment options. Although the documents emphasize the use of innovative technologies to address contamination, the use of other technologies also should be considered. For example, containment or more standard technology options also may be appropriate to address contamination at Brownfields sites. Examples of containment technologies include dynamic compaction, landfill reuse, and stabilization or solidification of contaminated material. Established technologies, such as incineration and pump-and-treat processes for groundwater contamination, also are alternatives to innovative technologies for use in addressing contamination.

When deciding between innovative and established technologies or between treatment and containment technologies, Brownfields stakeholders should compare the effectiveness and efficiency of each technology against the specific needs of the individual site and stakeholders. During this analysis, one should remember that technologies, or at least our understanding of them, change constantly.

Seeking External Support (Community Relations and Professional Support)

A wealth of information and expertise related to site cleanup is readily available. It is important that members of the Brownfields community have access to that information and are able to draw upon lessons learned to benefit from the experience of others.

Most decision makers at Brownfields sites will require technical and legal assistance to fully understand the complexities of investigating and cleaning up a contaminated site. In fact, some states may require the participation of certified or licensed professionals to help guide the site investigation and cleanup process. State regulatory agencies should be consulted to determine the requirements, if any, for the participation of certified or licensed cleanup professionals. It is recommended that site cleanup professionals and legal and other experts be recruited as members of the Brownfields team.

The Brownfields community can benefit from EPA's assistance in directing its members to appropriate resources and providing opportunities to network and participate in the sharing of information. A number of electronic bulletin boards and databases, newsletters, and reports provide opportunities for Brownfields stakeholders to network with other stakeholders to identify information about site cleanup and technology options. Such information resources are described below. Updates on regulatory development and business opportunities in the area of hazardous waste also are included.

Resources

Alternative Treatment Technology Information Center (ATTIC).

The Alternative Treatment Technology Information Center (ATTIC) is a comprehensive computer database system that provides up-to-date information on innovative treatment technologies. The database contains information on biological, chemical, and physical treatment processes; solidification and stabilization processes; and thermal treatment technologies. The on-line automated bibliographic reference integrates existing data on hazardous waste into a unified,



searchable resource. The ATTIC system provides users with access to several independent databases, an electronic bulletin board system, a hotline, and a repository of documents related to alternative and innovative treatment technologies. The ATTIC database can be accessed by modem at (703) 908-2138. Assistance can be reached at (703) 908-2137.

Bioremediation Action Committee: Fact Sheet (EPA 542-F-96-031).

The Bioremediation Action Committee (BAC) is a partnership of experts representing government, industry, and academia. The purpose of the BAC is to improve the use of bioremediation in the treatment, control, and prevention of environmental contamination and promote the use of bioremediation as a viable cleanup alternative for remediating hazardous waste sites. The Committee is co-chaired by representatives of EPA's TIO and the Office of Research and Development (ORD) and includes more than 100 experts in the field of bioremediation. The fact sheet describes the mission and structure of the BAC and its activities and provides information about products the BAC has developed. Points of contact also are identified.

Clean-Up Information (CLU-IN) Bulletin Board System.

CLU-IN The system is designed for use by hazardous waste cleanup professionals who need current information on innovative technologies for remediation and on access to EPA publications, other regularly updated information, and databases. CLU-IN can be accessed by modem at (301) 589-8366 or through the Internet at <http://clu-in.com>. Assistance can be reached at (301) 589-8368.

 A copy of the CLU-IN Brochure is provided on page A-91 in *Appendix A, Brownfields Site Cleanup "Starter Kit."*

Clean-Up Information Home Page on the World Wide Web (EPA 542-F-96-011).

CLU-IN The home page provides information about innovative treatment technologies to the hazardous waste remediation community. It describes programs, organizations, publications, and other tools for EPA and other Federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community

groups, and individual citizens. The home page can be accessed at <http://clu-in.com>.

Federal Remediation Technologies Roundtable: Five Years of Cooperation (EPA 542-F-95-007).

 The fact sheet provides information on the efforts of the Federal Remediation Technologies Roundtable for the past five years. The fact sheet also describes the initiatives, information sharing, ongoing cooperation, and future goals of the roundtable. A list of publications of the roundtable is included in the fact sheet. The fact sheet can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Ground Water Currents (EPA-542-N-96-003).

 The newsletter presents updated information about the development and use of innovative treatment technologies for groundwater. It also provides information on groundwater research and regulatory issues that affect the development and application of technologies. Issues published after January 1, 1996 can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

Ground-Water Remediation Technologies Analysis Center.

The Ground-Water Remediation Technologies Analysis Center (GWRTAC) was established through a cooperative agreement between the National Environmental Technology Applications Center (NETAC) of the Center for Hazardous Materials Research (CHMR) and EPA. The goal of GWRTAC is to compile, analyze, and disseminate information on innovative groundwater remediation technologies to industry, the research community, contractors, government, investors, and the public. The center currently is compiling information to be included in databases of interactive case studies and vendor information that will be available on the GWRTAC Web site. Additional information is available on the GWRTAC Web site at <http://www.gwrtac.org>.

Partnerships for the Remediation of Hazardous Wastes (EPA 542-R-96-006).

Prepared by EPA's TIO, the document provides potential private sector partners interested in the development of new and innovative hazardous

waste technologies with information about opportunities to participate in joint public-private development projects. The document also identifies points of contact and provides information about four programs through which EPA and other Federal agencies support technology development through partnerships with private entities. The purpose and activities of each program are summarized, and an order form is included for requesting additional information about the partnerships.

Progress in Reducing Impediments to the Use of Innovative Remediation Technology (EPA 542-F-95-008, PB95-262556).

The document highlights the accomplishments of TIO and its partners in advancing innovative treatment technologies. The accomplishments discussed include policy and regulatory improvements and improvements in research, development, and demonstration; information sharing; and training.

Public-Private Partnership Program for Evaluating Innovative Technologies: Fact Sheet (EPA 542-F-96-029).

The document provides information about the Public-Private Partnership Program, a project led by Clean Sites, Inc., a nonprofit public interest and research organization, under a cooperative agreement with EPA's TIO. The purpose of the program is to stimulate the use of innovative remedial technologies by establishing partnerships between Federal agencies and site owners from private industry for the joint implementation and evaluation of innovative technologies. The fact sheet describes the program, identifies its members, and explains the roles of the partnership members. Ongoing projects also are summarized, and points of contact are identified.

Remediation Technologies Development Forum Series.

The series of documents, prepared by EPA's ORD, summarizes the activities of the Remediation Technologies Development Forum (RTDF). The

RTDF is a consortium of partners representing industry, government agencies, and academia who work together to develop more effective, less costly hazardous waste characterization and treatment technologies. It is designed to foster public-private partnerships to conduct laboratory and field research to develop, test, and evaluate innovative technologies. Five Action Teams have been formed to address priority research areas in the development, testing, and evaluation of in situ remediation technologies. Each document in the series describes the purpose and activities of one of the Action Teams, identifies the participants in that team, and provides contact information. The various documents provide detailed information about:

- *Bioremediation of Chlorinated Solvents Consortium (EPA 542-F-96-010B)*
- *Lasagna™ Public-Private Partnership (EPA 542-F-96-010A)*
- *IINERT Soil-Metals Action Team (EPA 542-F-96-010D)*
- *Permeable Barriers Action Team (EPA 542-F-96-010C)*
- *Remediation Technologies Development Forum (EPA 542-F-96-010)*
- *Remediation Technologies Development Forum: Questions and Answers Fact Sheet (EPA 542-F-97-003)*

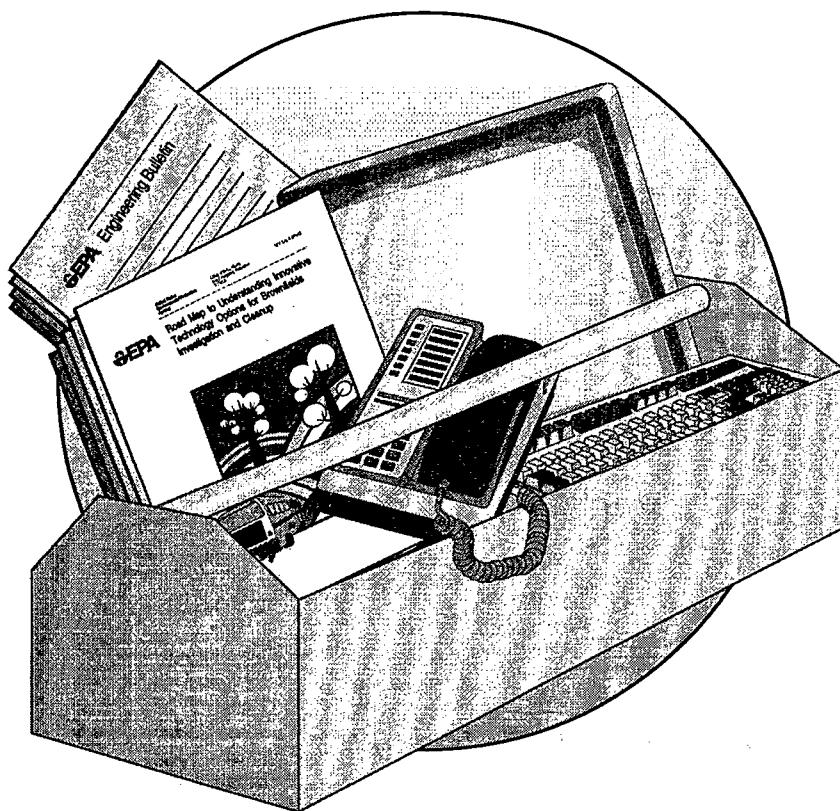


Tech Trends (EPA 542-N-96-002).

The newsletter presents information about applied technologies for site characterization and remediation. Among the issues addressed are new technologies, innovative uses of existing technologies, ways to overcome bureaucratic obstacles to the use of innovative technologies, and the applicability of innovative technologies in the Superfund program. The newsletter can be downloaded free of charge from the CLU-IN Web site at <http://clu-in.com>.

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APPENDICES

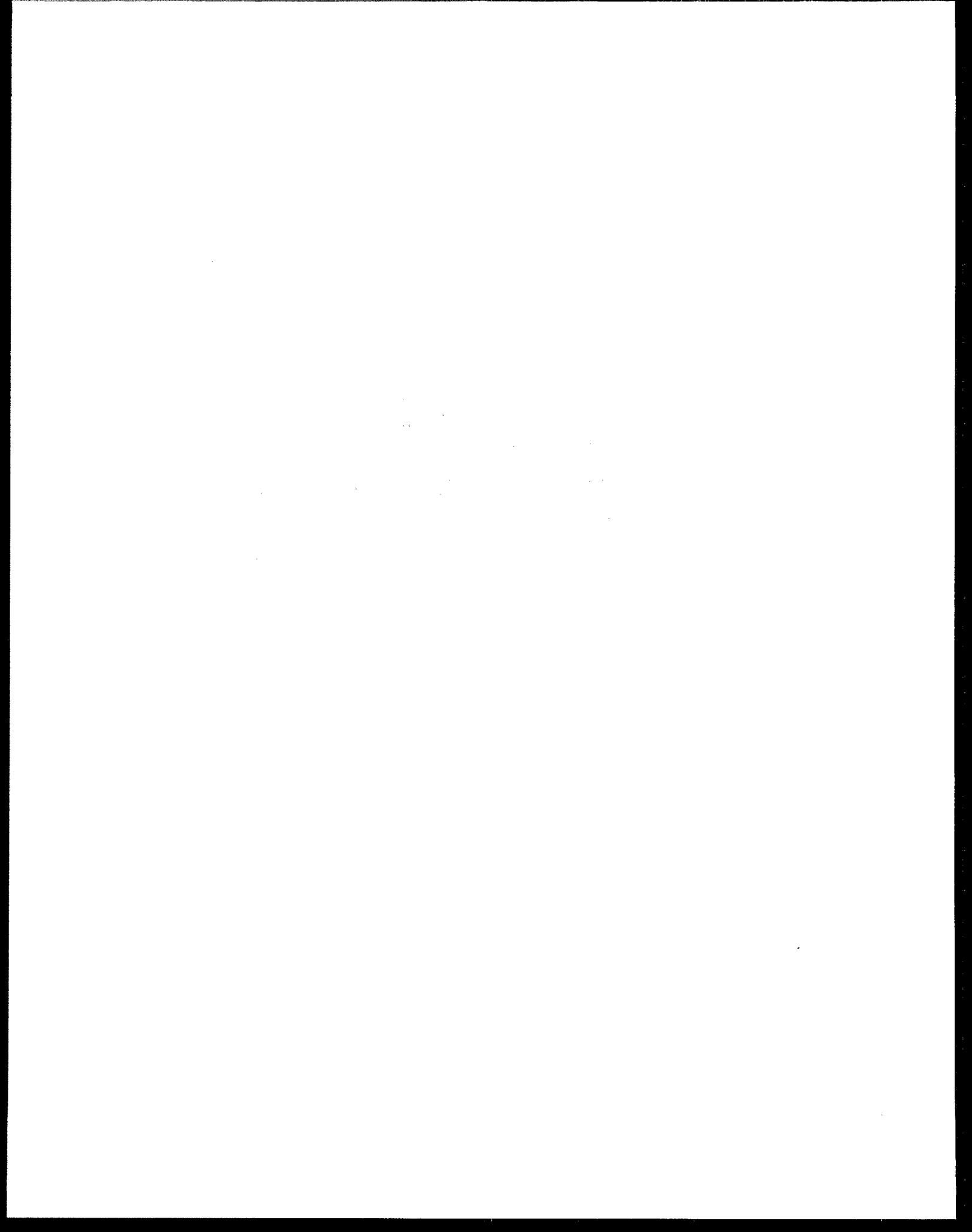


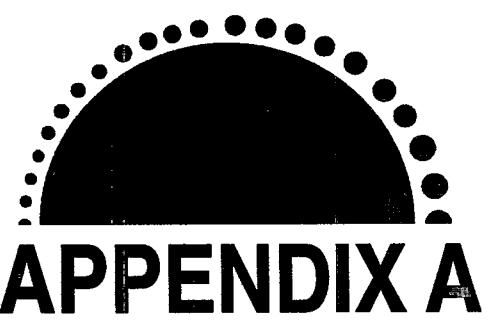
- A. Brownfields Site Cleanup
"Starter Kit"**

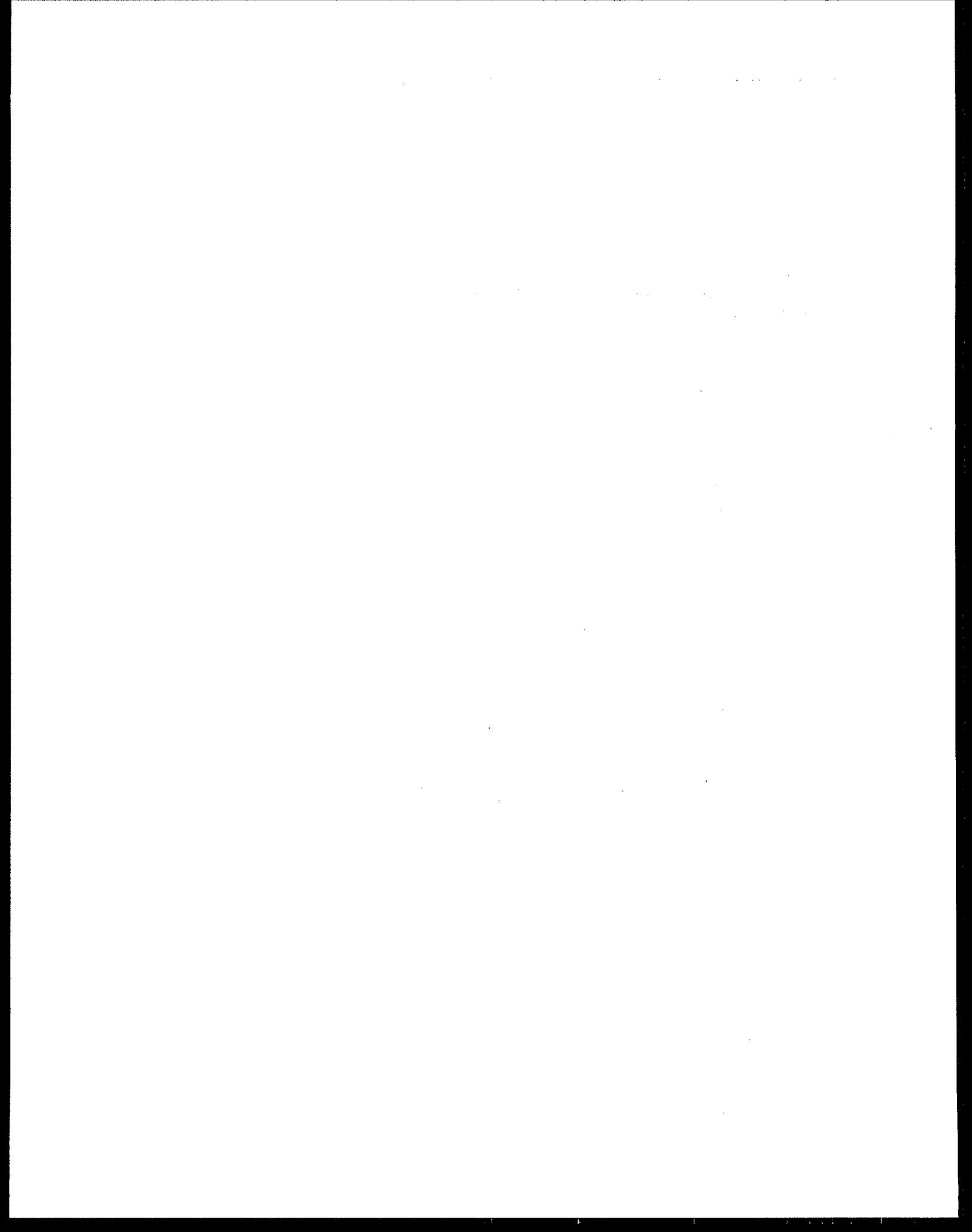
- B. List of Acronyms and Glossary
of Key Terms**

- C. List of Brownfields and
Technical Support Contacts**

- D. How to Order Documents**







Appendix A

BROWNFIELDS SITE CLEANUP “STARTER KIT”

The following is a “starter kit” of important information resources to give Brownfields stakeholders an example of the resources available to assist cleanup and redevelopment efforts at Brownfields sites. The documents in the “starter kit” include:

-  Citizen's Guides A-3
-  Clean-Up Information (CLU-IN) Bulletin Board System Brochure A-91
-  Remediation Technologies Screening Matrix A-93
-  Selecting Innovative Cleanup Technologies: EPA Resources A-95
-  List of Superfund Innovative Technology Evaluation (SITE) Program Reports A-105
-  Vendor Field Analytical and Characterization Technologies System (Vendor FACTS) Bulletin A-115
-  Vendor Information System for Innovative Treatment Technologies (VISITT) Bulletin A-123

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A Citizen's Guide to Bioremediation

Technology Innovation Office

Technology Fact Sheet

What is bioremediation?

Bioremediation is a treatment process that uses naturally occurring microorganisms (yeast, fungi, or bacteria) to break down, or *degrade*, hazardous substances into less toxic or nontoxic substances. Microorganisms, just like humans, eat and digest organic substances for nutrients and energy. In chemical terms, "organic" compounds are those that contain carbon and hydrogen atoms. Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans. The microorganisms break down the organic contaminants into harmless products—mainly carbon dioxide and water (Figure 1). Once the contaminants are degraded, the microorganism population is reduced because they have used all of their food source. Dead microorganisms or small populations in the absence of food pose no contamination risk.

How does it work?

Microorganisms must be active and healthy in order for bioremediation to take place. Bioremediation technologies assist microorganisms' growth and increase microbial populations by creating optimum environmental conditions for them to detoxify the maximum amount of contaminants. The specific bioremediation technology used is determined by several factors, for instance, the type of microorganisms present, the site conditions, and the quantity and toxicity of contaminant chemicals. Different microorganisms degrade different types of compounds and survive under different conditions.

Indigenous microorganisms are those microorganisms that are found already living at a given site. To stimulate the

growth of these indigenous microorganisms, the proper soil temperature, oxygen, and nutrient content may need to be provided.

If the biological activity needed to degrade a particular contaminant is *not* present in the soil at the site, microorganisms from other locations, whose effectiveness has been tested, can be added to the contaminated soil. These are called *exogenous* microorganisms. The soil conditions at the new site may need to be adjusted to ensure that the exogenous microorganisms will thrive.

Bioremediation can take place under *aerobic* and *anaerobic* conditions. In aerobic conditions, microorganisms use available atmospheric oxygen in order to function. With sufficient oxygen, microorganisms will convert many organic contaminants to carbon dioxide and water. *Anaerobic* conditions support biological activity in which no oxygen is present so the microorganisms break down chemical compounds in the soil to release the energy they need. Sometimes, during aerobic and anaerobic processes of breaking down the original contaminants, intermediate products that are less, equally, or more toxic than the original contaminants are created.

Bioremediation can be used as a cleanup method for contaminated soil and water. Bioremediation applications fall into two broad categories: *in situ* or *ex situ*. *In situ* bioremediation treats the contaminated soil or groundwater in the location in which it was found. *Ex situ* bioremediation processes require excavation of contaminated soil or pumping of groundwater before they can be treated.

A Quick Look at Bioremediation

- Uses naturally occurring microorganisms to break down hazardous substances into less toxic or nontoxic substances.
- A cost effective, natural process applicable to many common organic wastes.
- Many techniques can be conducted on-site.



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In Situ Bioremediation of Soil

In situ techniques do not require excavation of the contaminated soils so may be less expensive, create less dust, and cause less release of contaminants than ex situ techniques. Also, it is possible to treat a large volume of soil at once. In situ techniques, however, may be slower than ex situ techniques, may be difficult to manage, and are most effective at sites with *permeable* (sandy or uncompacted) soil.

The goal of aerobic in situ bioremediation is to supply oxygen and nutrients to the microorganisms in the soil. Aerobic in situ techniques can vary in the way they supply oxygen to the organisms that degrade the contaminants. Two such methods are **bioventing** and **injection of hydrogen peroxide**. Oxygen can be provided by pumping air into the soil above the water table (bioventing) or by delivering the oxygen in liquid form as hydrogen peroxide. In situ bioremediation may not work well in clays or in highly layered subsurface environments because oxygen cannot be evenly distributed throughout the treatment area. In situ remediation often requires years to reach cleanup goals, depending mainly on how biodegradable specific contaminants are. Less time may be required with easily degraded contaminants.

Bioventing. Bioventing systems deliver air from the atmosphere into the soil above the water table through injection wells placed in the ground where the contamination exists. The number, location, and depth of the wells depend on many geological factors and engineering considerations.

An air blower may be used to push or pull air into the soil through the injection wells. Air flows through the soil and the oxygen in it is used by the microorganisms. Nutrients may be pumped into the soil through the injection wells. Nitrogen and phosphorous may be added to increase the growth rate of the microorganisms.

Injection of Hydrogen Peroxide. This process delivers oxygen to stimulate the activity of naturally occurring microorganisms by circulating hydrogen peroxide through contaminated soils to speed the bioremediation of organic contaminants. Since it involves putting a chemical (hydrogen peroxide) into the ground (which may eventually seep into the groundwater), this process is used only at sites where the groundwater is already contaminated.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to the treatment of hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. *Innovative treatment technologies* are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

A system of pipes or a sprinkler system is typically used to deliver hydrogen peroxide to shallow contaminated soils. Injection wells are used for deeper contaminated soils.

In Situ Bioremediation of Groundwater

In situ bioremediation of groundwater speeds the natural biodegradation processes that take place in the water-soaked underground region that lies below the water table. For sites at which both the soil and groundwater are contaminated, this single technology is effective at treating both.

Generally, an in situ groundwater bioremediation system consists of an extraction well to remove groundwater from the ground, an above-ground water treatment system where nutrients and an oxygen source may be added to the contaminated groundwater, and injection wells to return the "conditioned" groundwater to the subsurface where the microorganisms degrade the contaminants.

One limitation of this technology is that differences in underground soil layering and density may cause reinjected conditioned groundwater to follow certain preferred flow paths. Consequently, the conditioned water may not reach some areas of contamination.

Another frequently used method of in situ groundwater treatment is *air sparging*, which means pumping air into the groundwater to help flush out contaminants. Air sparging is used in conjunction with a technology called soil vapor extraction and is described in detail in the document entitled *A Citizen's Guide to Soil Vapor Extraction and Air Sparging* (see page 4).

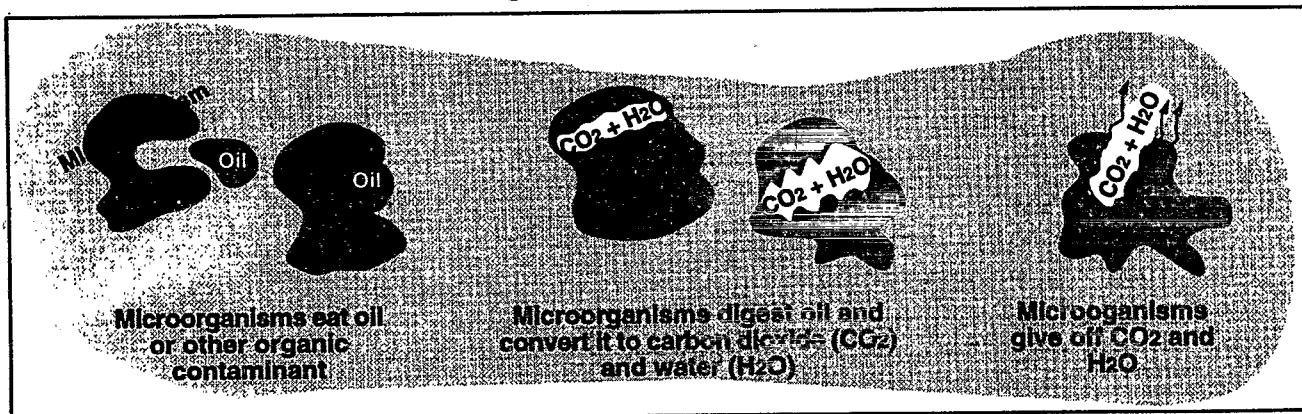
Ex Situ Bioremediation of Soil

Ex situ techniques can be faster, easier to control, and used to treat a wider range of contaminants and soil types than in situ techniques. However, they require excavation and treatment of the contaminated soil before and, sometimes, after the actual bioremediation step. Ex situ techniques include **slurry-phase bioremediation** and **solid-phase bioremediation**.

Slurry-phase bioremediation. Contaminated soil is combined with water and other additives in a large tank called a "bioreactor" and mixed to keep the microorganisms—which are already present in the soil—in contact with the contaminants in the soil. Nutrients and oxygen are added, and conditions in the bioreactor are controlled to create the optimum environment for the microorganisms to degrade the contaminants. Upon completion of the treatment, the water is removed from the solids, which are disposed of or treated further if they still contain pollutants.

Slurry-phase biological treatment can be a relatively rapid process compared to other biological treatment processes, particularly for contaminated clays. The success of the process is highly dependent on the specific soil and chemical properties of the contaminated material. This technology is particularly useful where rapid remediation is a high priority.

Figure 1
Schematic Diagram of Aerobic Biodegradation in Soil



Solid-phase bioremediation. Solid-phase bioremediation is a process that treats soils in above-ground treatment areas equipped with collection systems to prevent any contaminant from escaping the treatment. Moisture, heat, nutrients, or oxygen are controlled to enhance biodegradation for the application of this treatment. Solid-phase systems are relatively simple to operate and maintain, require a large amount of space, and cleanups require more time to complete than with slurry-phase processes. Solid-phase soil treatment processes include *landfarming*, *soil biopiles*, and *composting*.

Landfarming. In this relatively simple treatment method, contaminated soils are excavated and spread on a pad with a built-in system to collect any "leachate" or contaminated liquids that seep out of contaminant-soaked soil. The soils are periodically turned over to mix air into the waste. Moisture and nutrients are controlled to enhance bioremediation. The length of time for bioremediation to occur will be longer if nutrients, oxygen or temperature are not properly controlled. In some cases, reduction of contaminant concentrations actually may be attributed more to volatilization than biodegradation. When the process is conducted in enclosures controlling escaping volatile contaminants, volatilization losses are minimized.

Soil biopiles. Contaminated soil is piled in heaps several meters high over an air distribution system. Aeration is provided by pulling air through the heap with a vacuum pump. Moisture and nutrient levels are maintained at levels that maximize bioremediation. The soil heaps can be placed in enclosures. Volatile contaminants are easily controlled since they are usually part of the air stream being pulled through the pile.

Composting. Biodegradable waste is mixed with a bulking agent such as straw, hay, or corn cobs to make it easier to deliver the optimum levels of air and water to the microorganisms. Three common designs are *static pile composting* (compost is formed into piles and aerated with blowers or vacuum pumps), *mechanically agitated in-vessel*

composting (compost is placed in a treatment vessel where it is mixed and aerated), and *window composting* (compost is placed in long piles known as windrows and periodically mixed by tractors or similar equipment).

Will it work at every site?

Biodegradation is useful for many types of organic wastes and is a cost-effective, natural process. Many techniques can be conducted on-site, eliminating the need to transport hazardous materials.

The extent of biodegradation is highly dependent on the toxicity and initial concentrations of the contaminants, their biodegradability, the properties of the contaminated soil, and the particular treatment system selected.

Contaminants targeted for biodegradation treatment are non-halogenated volatile and semi-volatile organics and fuels. The effectiveness of bioremediation is limited at sites with high concentrations of metals, highly chlorinated organics, or inorganic salts because these compounds are toxic to the microorganisms.

Where has it been used?

At the Scott Lumber Company Superfund site in Missouri, 16,000 tons of soils contaminated with polycyclic aromatic hydrocarbons (PAHs) were biologically treated using land treatment application. PAH concentrations were reduced by 70%.

At the French Ltd. Superfund site in Texas, slurry-phase bioremediation was used to treat 300,000 tons of lagoon sediment and tar-like sludge contaminated with volatile organic compounds, semi-volatile organic compounds, metals, and pentachlorophenol. Over a period of 11 months, the treatment system was able to meet the cleanup goals set by EPA.

Some additional examples of Superfund sites where different types of bioremediation have been selected as a treatment method are listed in Table 1 on page 4.

Table 1
Examples of Superfund Sites Using Bioremediation Technologies*

Name of Site	Treatment	Contaminants
Applied Environmental Services, NY	Bioventing	Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs)
Onalaska Municipal Landfill, WI	Bioventing	VOCs, polycyclic aromatic hydrocarbons (PAHs)
Eielson Air Force Base, AK	Bioventing	VOCs, SVOCs, PAHs
Brown Wood Preserving, FL	Land treatment	PAHs
Vogel Paint & Wax, IA	Land treatment	VOCs
Broderick Wood Products, CO	Land treatment/Bioventing	SVOCs, PAHs, dioxins
Burlington Northern (Somers), MT	Land treatment/ In Situ Bioremediation	SVOCs, PAHs

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

*Not all waste types and site conditions are comparable. Each site must be individually investigated and tested. Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

For More Information

The publications listed below can be ordered free of charge by calling NCEPI at 513-489-8190 or faxing your request to 513-489-8695. If NCEPI is out of stock of a document, you may be directed to other sources. Write to NCEPI at:

National Center for Environmental Publications and Information (NCEPI)
 P.O. Box 42419
 Cincinnati, OH 45242

- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Sources*, January 1995, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Bioremediation Resource Guide*, September 1993, EPA 542-B-93-004. A bibliography of publications and other sources of information about bioremediation technologies.
- *A Citizen's Guide to Soil Vapor Extraction and Air Sparging*, EPA 542-F-96-008
- *Engineering Bulletin: In Situ Biodegradation Treatment*, April 1994, EPA 540-S-94-502.
- *Engineering Bulletin: Slurry Biodegradation*, September 1990, EPA 540-2-90-016.
- *Abstracts of Remediation Case Studies*, March 1995, EPA 542-R-95-001.
- *WASTECH® Monograph on Bioremediation*, ISBN #1-883767-01-6. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: Medidas biocorrectivas

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué son las medidas biocorrectivas?

Las medidas biocorrectivas consisten en el uso de microorganismos naturales (levaduras, hongos o bacterias) para descomponer o *degradar* sustancias peligrosas en sustancias menos tóxicas o que no sean tóxicas. Los microorganismos, igual que los seres humanos, comen y digieren sustancias orgánicas, de las cuales obtienen nutrientes y energía. En términos químicos, los compuestos "orgánicos" son aquellos que contienen átomos de carbono e hidrógeno. Ciertos microorganismos pueden digerir sustancias orgánicas peligrosas para los seres humanos, como combustibles o solventes. Los microorganismos descomponen los contaminantes orgánicos en productos inocuos, principalmente dióxido de carbono y agua (figura 1). Una vez degradados los contaminantes, la población de microorganismos se reduce porque ha agotado su fuente de alimentos. Las poblaciones pequeñas de microorganismos sin alimentos o los microorganismos muertos no presentan riesgos de contaminación.

¿Cómo funcionan?

Los microorganismos deben estar activos y saludables para que puedan desempeñar su tarea correctiva. Las medidas biocorrectivas facilitan el crecimiento de los microorganismos y aumentan la población microbiana creando condiciones ambientales óptimas para que puedan destoxicificar la mayor cantidad posible de contaminantes. La medida biocorrectiva que se use dependerá de varios factores, entre ellos el tipo de microorganismos presentes, las condiciones del lugar y la cantidad y toxicidad de los productos químicos contaminantes. Hay diversos microorganismos que degradan distintos tipos de compuestos y sobreviven en condiciones diferentes.

Los microorganismos *autóctonos* son los que ya viven en un lugar determinado. Para estimular su crecimiento, tal vez sea necesario proporcionarles una temperatura apropiada del suelo, oxígeno y nutrientes.

Si la actividad biológica que se necesita para degradar un contaminante en particular *no* está presente en el suelo del lugar, se pueden añadir al suelo contaminado microorganismos de otros lugares cuya eficacia se haya comprobado. Estos son microorganismos *exógenos*. Es posible que haya que modificar las condiciones del suelo del lugar nuevo para que los microorganismos exógenos proliferen.

Las medidas biocorrectivas pueden aplicarse en condiciones *aerobias* y *anaerobias*. En condiciones aerobias, los microorganismos usan el oxígeno disponible en la atmósfera para funcionar. Con suficiente oxígeno, los microorganismos convertirán muchos contaminantes orgánicos en dióxido de carbono y agua. En condiciones anaerobias, la actividad biológica tiene lugar en ausencia de oxígeno, de modo que los microorganismos descomponen compuestos químicos del suelo para liberar la energía que necesitan. A veces, en los procesos aerobios y anaerobios de descomposición de los contaminantes originales se crean productos intermedios de toxicidad menor, igual o mayor.

Las medidas biocorrectivas pueden usarse como método para descontaminar el suelo y el agua. Estas medidas se clasifican en dos grandes categorías: *in situ* y *ex situ*. Con medidas biocorrectivas *in situ* se trata la tierra contaminada o el agua subterránea en el lugar donde se encuentra. Las medidas biocorrectivas *ex situ* consisten en excavar el suelo contaminado o extraer el agua subterránea por bombeo para aplicar el tratamiento.

Medidas biocorrectivas *in situ* para el suelo

Con las técnicas *in situ* no es necesario excavar el suelo contaminado, de modo que son menos costosas, levantan menos polvo y liberan menos contaminantes que las técnicas *ex situ*. Además, se puede tratar una gran cantidad de tierra por vez. Sin embargo, las técnicas *in situ* pueden llevar más tiempo que las técnicas *ex situ*, pueden ser difíciles de manejar y son más eficaces en suelos *permeables* (arenosos o que no sean compactos).

Perfil de las medidas biocorrectivas

- Se usan microorganismos naturales para descomponer sustancias peligrosas en sustancias menos tóxicas o que no sean tóxicas.
- Es un proceso natural, eficaz en función del costo, que puede aplicarse a muchos desechos orgánicos comunes.
- Muchas de las técnicas pueden aplicarse *in situ*.

La meta de las medidas biocorrectivas in situ en condiciones aerobias es suministrar oxígeno y nutrientes a los microorganismos del suelo. Las técnicas aerobias in situ varían en cuanto al método de suministro de oxígeno a los microorganismos que degradan los contaminantes. Dos de esos métodos son la bioaireación y la inyección de peróxido de hidrógeno. Se puede suministrar oxígeno introduciendo aire por bombeo en el suelo, arriba de la capa freática (bioaireación), o en forma líquida como peróxido de hidrógeno. Las medidas biocorrectivas in situ tal vez no den buenos resultados en suelos arcillosos o en subsuelos altamente estratificados porque no se puede distribuir oxígeno de manera uniforme en toda la zona que necesita tratamiento. Con medidas biocorrectivas in situ a veces se tarda años en alcanzar las metas en cuanto a limpieza, dependiendo principalmente de cuán biodegradables sean determinados contaminantes. Con contaminantes que se degradan fácilmente quizás se tarde menos.

Bioaireación. Los sistemas de bioaireación introducen aire de la atmósfera en el suelo, arriba de la capa freática, por medio de pozos de inyección situados en el lugar contaminado. La cantidad, la ubicación y la profundidad de los pozos dependen de muchos factores geológicos y consideraciones técnicas.

Se puede usar un ventilador para forzar la entrada de aire en el suelo por empuje o tracción por los pozos de inyección. El aire fluye por el suelo, y los microorganismos usan el oxígeno del aire. Por los pozos de inyección se pueden introducir también nutrientes, como nitrógeno y fósforo, para acelerar el crecimiento de los microorganismos.

Inyección de peróxido de hidrógeno. Con esta técnica se suministra oxígeno para estimular la actividad de microorganismos naturales haciendo circular peróxido de hidrógeno por el suelo contaminado para acelerar la eliminación biológica de contaminantes orgánicos. Como consiste en introducir una sustancia química (peróxido de hidrógeno) en el suelo (que podría infiltrarse hasta llegar al agua subterránea), se usa solamente en lugares donde el agua subterránea ya está contaminada.

Generalmente se usa un sistema de tuberías o de aspersores para introducir peróxido de hidrógeno en suelos contaminados a poca profundidad. Para suelos contaminados a mayor profundidad se usan pozos de inyección.

Medidas biocorrectivas in situ para el agua subterránea
Las medidas biocorrectivas in situ para el agua subterránea aceleran los procesos naturales de biodegradación que tienen

¿Qué son las técnicas de tratamiento innovadoras?

Las técnicas de tratamiento son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Las técnicas de tratamiento innovadoras son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

lugar en la región subterránea empapada en agua que está debajo de la capa freática. En los lugares donde tanto el suelo como el agua subterránea están contaminados, esta técnica sirve para tratar ambos.

Por lo general, un sistema biocorrectivo in situ para el agua subterránea consiste en un pozo de extracción para sacar el agua subterránea del suelo, un sistema de tratamiento del agua en la superficie, con el cual se pueden agregar nutrientes y una fuente de oxígeno al agua subterránea contaminada, y pozos de inyección para reintroducir el agua subterránea "acondicionada" en el subsuelo, donde los microorganismos degradan los contaminantes.

Una de las limitaciones de esta técnica es que las diferencias en la disposición y la densidad de las capas del suelo podrían llevar al agua subterránea acondicionada reinyectada a seguir ciertos trayectos preferidos, sin llegar nunca a algunos lugares contaminados.

Otro método que se usa con frecuencia para el tratamiento in situ de agua subterránea es la *aspersión de aire*, que consiste en introducir aire por bombeo en el agua subterránea para que arrastre los contaminantes. La aspersión de aire se usa junto con la técnica de extracción de vapores del suelo, que se describe con pormenores en la *Guía del ciudadano: La extracción de vapores del suelo y la aspersión de aire* (véase la página 4).

Medidas biocorrectivas ex situ para el suelo

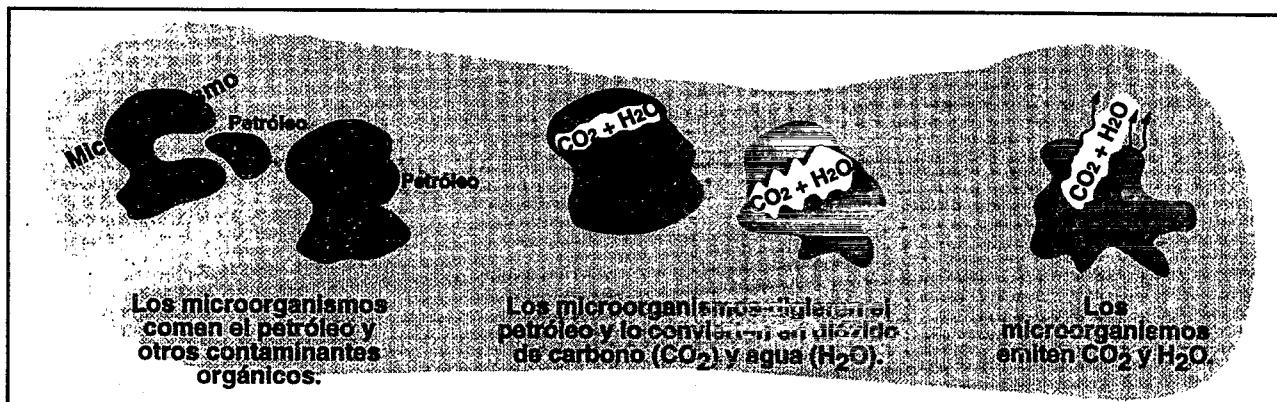
Las técnicas ex situ llevan menos tiempo, son más fáciles de controlar y se usan para tratar una gama más amplia de contaminantes y tipos de suelo que las técnicas in situ. Sin embargo, requieren la excavación y el tratamiento del suelo contaminado antes de la medida biocorrectiva en sí y, a veces, incluso después. Entre las técnicas ex situ cabe señalar las **medidas biocorrectivas de fase de lechada** y las **medidas biocorrectivas de fase sólida**.

Medidas biocorrectivas de fase de lechada. La tierra contaminada se combina con agua y otros aditivos en un tanque grande denominado "biorreactor", se mezcla para mantener los microorganismos presentes en la tierra en contacto con los contaminantes y se añaden nutrientes y oxígeno. Las condiciones en el biorreactor se controlan a fin de crear el medio óptimo para que los microorganismos degraden los contaminantes. Una vez concluido el tratamiento, se separa el agua de los sólidos, que se eliminan o son sometidos a un tratamiento ulterior si todavía tienen contaminantes.

El tratamiento biológico de fase de lechada puede ser relativamente rápido en comparación con otros tratamientos biológicos, particularmente para la arcilla contaminada. El éxito del proceso depende en gran medida del tipo de suelo y de las propiedades químicas del material contaminado. Esta técnica es particularmente útil en los casos en que se necesitan medidas correctivas rápidas.

Medidas biocorrectivas de fase sólida. Con medidas biocorrectivas de fase sólida, se somete la tierra a un tratamiento en la superficie con sistemas de recolección para evitar la fuga de contaminantes. Se controla la humedad, el calor, los nutrientes y el oxígeno a fin de propiciar la biodegradación para aplicar este tratamiento.

Figura 1
Esquema de la biodegradación aerobia en el suelo



Los sistemas de fase sólida son relativamente sencillos de usar y de mantener, aunque ocupan mucho lugar y la limpieza lleva más tiempo que con los procesos de fase de lechada. Los sistemas de tratamiento de fase sólida abarcan el tratamiento de la tierra, biopilas de tierra y la producción de abonos a partir de desechos.

Tratamiento de la tierra. Con este método de tratamiento relativamente sencillo, se excava el suelo contaminado y se esparce la tierra en una plataforma con un sistema incorporado para recoger cualquier "lixiviado" o líquido contaminado que se escurre del suelo empapado en contaminantes. Se da vuelta la tierra periódicamente para mezclar aire con los desechos. Asimismo, se controla la humedad y los nutrientes para propiciar la acción biocorrectiva. La biocorrección llevará más tiempo si los nutrientes, el oxígeno o la temperatura no están bien controlados. En algunos casos, la reducción de la concentración de contaminantes podría atribuirse más a la volatilización que a la biodegradación. Cuando el proceso tiene lugar en lugares cerrados donde se controlan los contaminantes volátiles que se escapan, las pérdidas por volatilización se reducen al mínimo.

Biopilas de tierra. La tierra contaminada se amontona en pilas de varios metros de altura sobre un sistema de distribución de aire. La aireación se realiza forzando el paso del aire por el montón de tierra con una bomba de vacío. La humedad y los nutrientes se mantienen en un nivel óptimo para la acción biocorrectiva. Los montones de tierra pueden colocarse en lugares cerrados. Los contaminantes volátiles son fáciles de controlar porque generalmente se integran a la corriente de aire que se hace pasar por la pila.

Producción de abono a partir de desechos. Se mezclan desechos biodegradables con un agente que les dé más volumen, como paja, heno o mazorcas, para facilitar el suministro de la cantidad óptima de aire y agua a los microorganismos. Tres tipos comunes son la *producción de abono en pilas estáticas* (se forman pilas de desechos aireadas con ventiladores impelentes o bombas de vacío), la *producción de abono en recipientes con agitación mecánica* (los desechos se colocan en un recipiente para el tratamiento donde se mezclan y airean) y *producción de*

abono en hileras (los desechos se colocan en pilas alargadas, o sea hileras, y se mezclan periódicamente usando tractores o equipo similar).

¿Dará resultado esta técnica en cualquier lugar?

La biodegradación sirve para muchos tipos de desechos orgánicos y es un proceso natural y eficiente en función del costo. Muchas técnicas pueden aplicarse *in situ*, evitando la necesidad de transportar materiales peligrosos.

El grado de biodegradación depende principalmente de la toxicidad y de la concentración inicial de contaminantes, su biodegradabilidad, las propiedades del suelo contaminado y el sistema de tratamiento que se seleccione.

Los contaminantes que se pueden biodegradar son compuestos orgánicos no halogenados, tanto volátiles como semivolátiles, y combustibles. La eficacia de las medidas biocorrectivas es limitada en lugares con una alta concentración de metales, compuestos orgánicos altamente clorados o sales inorgánicas porque estos compuestos son tóxicos para los microorganismos.

¿Dónde se ha usado esta técnica?

En el predio de Scott Lumber Company (Misuri), uno de los sitios comprendidos en el *Superfund*, se aplicó un tratamiento biológico a 16.000 toneladas de tierra contaminada con hidrocarburos poliaromáticos, usando la técnica de tratamiento de la tierra. Se logró una reducción del 70% en la concentración de hidrocarburos.

En el sitio de French Ltd. (Texas), también comprendido en el *Superfund*, se usaron medidas biocorrectivas de fase de lechada para tratar 300.000 toneladas de sedimentos de una laguna y fango residual tipo alquitrán contaminados con compuestos orgánicos volátiles y semivolátiles, metales y pentaclorofenol. Con este sistema de tratamiento, las metas de limpieza establecidas por el EPA se alcanzaron en el plazo de 11 meses.

En el cuadro 1 de la página 4 hay más ejemplos de lugares donde se han seleccionado distintos tipos de medidas biocorrectivas como método de tratamiento con recursos del *Superfund*.

Cuadro 1
Ejemplos de sitios donde se usan técnicas biocorrectivas con recursos del Superfund*

Nombre del sitio	Tratamiento	Contaminantes
Applied Environmental Services (Nueva York)	Bioaireación	Compuestos orgánicos volátiles, compuestos orgánicos semivolátiles
Onalaska Municipal Landfill (Wisconsin)	Bioaireación	Compuestos orgánicos volátiles, hidrocarburos poliaromáticos
Eielson Air Force Base (Arkansas)	Bioaireación	Compuestos orgánicos volátiles, compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos
Brown Wood Preserving (Florida)	Tratamiento de la tierra	Hidrocarburos poliaromáticos
Vogel Paint & Wax (Indiana)	Tratamiento de la tierra	Compuestos orgánicos volátiles
Broderick Wood Products (Colorado)	Tratamiento de la tierra y bioaireación	Compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos, dioxinas
Burlington Northern (Somers) (Montana)	Tratamiento de la tierra y medidas biocorrectivas in situ	Compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Hay una base de datos con más información sobre los sitios indicados en el Annual Status Report. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discetes. Consulte al NCEPI para más pormenores.

* No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

Para más información:

Las publicaciones que se indican a continuación pueden obtenerse gratis del NCEPI. Para encargarlas, envíe su pedido por fax al 513-489-8695. Si al NCEPI no le quedan más ejemplares de alguno de estos documentos, puede dirigirse a otras fuentes. Escriba al NCEPI a la siguiente dirección:

National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242

- Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources, enero de 1995, EPA 542-B-95-001. **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- Bioremediation Resource Guide, septiembre de 1993, EPA 542-B-93-004. **Bibliografía de publicaciones y otras fuentes de información sobre técnicas biocorrectivas.**
- A Citizen's Guide to Soil Vapor Extraction and Air Sparging, EPA 542-F-96-008.
- Engineering Bulletin: In Situ Biodegradation Treatment, abril de 1994, EPA 540-S-94-502.
- Engineering Bulletin: Slurry Biodegradation, septiembre de 1990, EPA 540-2-90-016.
- Abstracts of Remediation Case Studies, EPA 542-R-95-001.
- WASTECH® Monograph on Bioremediation, ISBN #1-883767-01-6. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Chemical Dehalogenation

Technology Innovation Office

Technology Fact Sheet

What is chemical dehalogenation?

Chemical dehalogenation is a chemical process to remove *halogens* (usually chlorine) from a chemical contaminant, rendering it less hazardous. *Halogens* are a class of chemical elements that include chlorine, bromine, iodine, and fluorine. Polychlorinated biphenyls are halogenated compounds that once were used in high voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. In addition, halogenated compounds are used to produce pesticides because their addition causes the toxicity needed to control pests. Halogenated compounds also are commonly used in water treatment, swimming pool chemicals, and plastic piping and textile production. The chemical dehalogenation process can be used on common halogenated contaminants such as PCBs and dioxins which are usually found in soil and oils.

How does it work?

There are two common versions of the chemical dehalogenation process in use: glycolate dehalogenation and the base-catalyzed decomposition process.

Glycolate Dehalogenation

Glycolate dehalogenation makes use of a chemical reagent called APEG. APEG consists of two parts: an alkali metal hydroxide (the "A" in APEG) and

polyethylene glycol (PEG), a substance similar to anti-freeze. Sodium hydroxide and potassium hydroxide are two common alkali metal hydroxides. Potassium polyethylene glycolate is the most common APEG reagent. The process consists of mixing and heating the contaminated soils with the APEG reagent. During heating, the alkali metal hydroxide reacts with the halogen from the contaminant to form a non-toxic salt; and the PEG takes the location in the PCB molecule formerly occupied by the halogen making it less hazardous.

The glycolate dehalogenation process consists of five steps: preparation, reaction, separation, washing, and dewatering (Figure 1). During the preparation step, the contaminated waste (soil, for example) is excavated and sifted to remove debris and large objects such as boulders and logs. Next, in the reaction step, the contaminated soils and the APEG reagent are blended in a large container called a *reactor*, mixed, and heated for four hours.

Vapors resulting from the heating process are collected. The vapor is separated into water and the gaseous contaminants by means of a condenser. The water can be used during a later step in the process and the gaseous contaminants are passed through activated carbon filters to capture the contaminant.

A Quick Look at Chemical Dehalogenation

- Used to treat halogenated aromatic organic contaminants, particularly PCBs and dioxins.
- Chemically converts toxic materials to less toxic or non-toxic materials.
- Involves heating and physically mixing contaminated soils with chemical reagents.
- Is a transportable technology that can be brought to the site.

The soil-APEG mixture, after treatment in the reactor, goes to the separator, where the APEG reagent is separated from the soil and recycled for future use in the system. The treated soil contains products of the treatment which are less toxic chemicals resulting from the dehalogenation reaction. These new chemical products are a non-toxic salt and a less toxic, partially dehalogenated organic compound.

The soil passes from the separation step to a washer, where the water collected in the earlier reaction step is added. The last traces of residual APEG reagent are extracted from the soil and recycled. The soil proceeds to a dewatering phase where the water and soil are separated. The water is treated to remove contaminants before discharge to a municipal water treatment system, a receiving stream, or other appropriate discharge areas. The soil is retested for contaminant concentrations. If it still contains contaminants above targeted treatment concentrations, it is recycled through the process or put into an environmentally safe landfill; if the soil is clean, it can be returned to its original location on the site.

Base-Catalyzed Decomposition

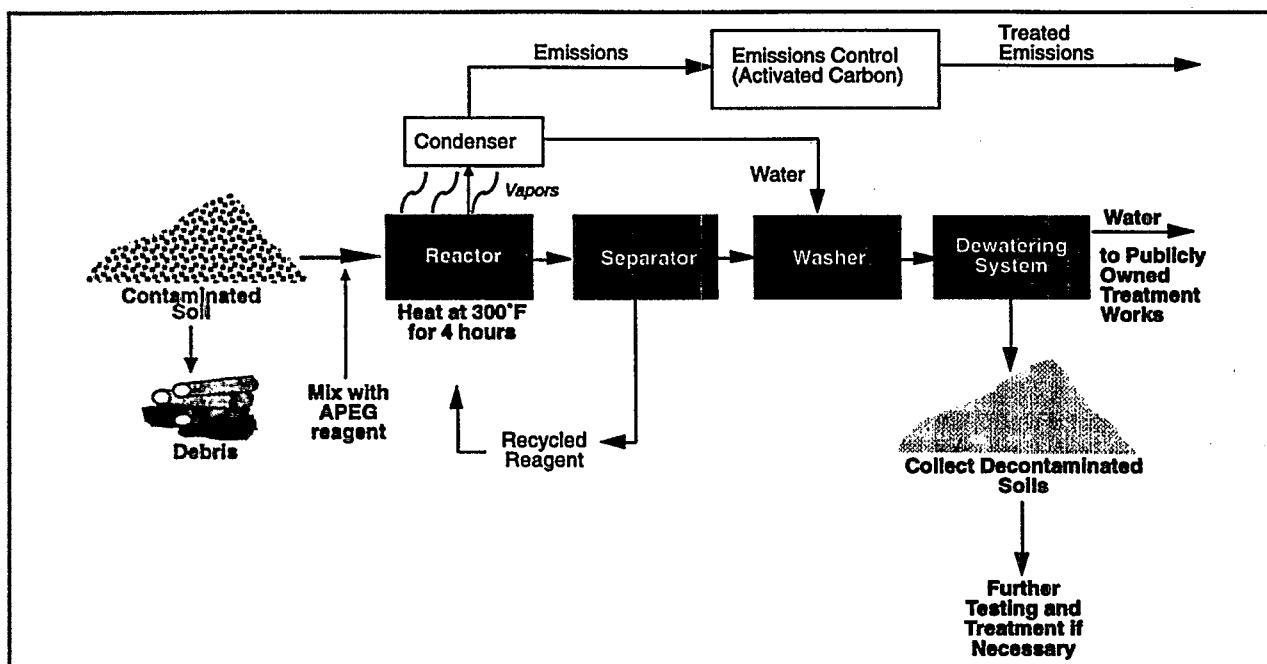
A second type of chemical dehalogenation, the base-catalyzed decomposition (BCD) process, was developed by the U.S. Environmental Protection Agency as a clean, inexpensive way to remediate liquids, sludge,

soil, and sediment contaminated with chlorinated organic compounds, especially PCBs, pesticides, some herbicides and dioxins.

In the BCD process (Figure 2 on page 3), contaminated soil is excavated and screened to remove debris and large particles, then crushed and mixed with sodium bicarbonate at roughly one part sodium bicarbonate to ten parts soil. This mixture is heated in a reactor. The heat separates the halogenated compounds from the soil by evaporation. The soil left behind is removed from the reactor and can be returned to the site. The contaminated gases, condensed into a liquid form, pass into a liquid-phase reactor. The dehalogenation reaction occurs when several chemicals including sodium hydroxide (a base) are mixed with the condensed contaminants and heated in the reactor. The resulting liquid mixture can be incinerated or treated by other technologies and recycled. The BCD process eliminates the need to remove the reactants from the treated soil as in the glycolate dehalogenation process.

The BCD process components are easily transported and safely operated. The process employs off-the-shelf equipment and requires less time and space to mobilize, set up, and take down than an incinerator—which is a common alternative treatment for PCB-contaminated wastes.

Figure 1
The Glycolate Dehalogenation Process



What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so that they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste. *Innovative treatment technologies* are those that have been tested, selected, or used for treatment of hazardous waste or contaminated materials but still lack well-documented cost and performance data under a variety of operating conditions.

Why consider chemical dehalogenation?

Dehalogenation can be an effective process for removing halogens from hazardous organic compounds, such as dioxins, furans, PCBs, and certain chlorinated pesticides. The treatment time is short, energy requirements are moderate, and operation and maintenance costs are relatively low. The technology can be brought to the site, so hazardous wastes do not have to be transported.

Will dehalogenation work at every site?

Characteristics of the contaminated material that interfere with the effectiveness of chemical dehalogenation are high clay or water content, acidity, or high natural

organic content of the soil. Glycolate dehalogenation is not designed for large waste volumes or wastes with concentrations of chlorinated contaminants above 5%. Since contaminated soil must be excavated and screened before treatment, there must be sufficient space at the site to conduct this pretreatment process.

Where is dehalogenation being used?

Some Superfund sites where chemical dehalogenation has been selected as a treatment method are listed in Table 1 on page 4. The BCD process also has been used by the Navy at a Public Works Center in Guam to treat PCB-contaminated soil. The BCD process was successful at meeting EPA's cleanup goals for the soil.

Figure 2
The Base-Catalyzed Decomposition Process

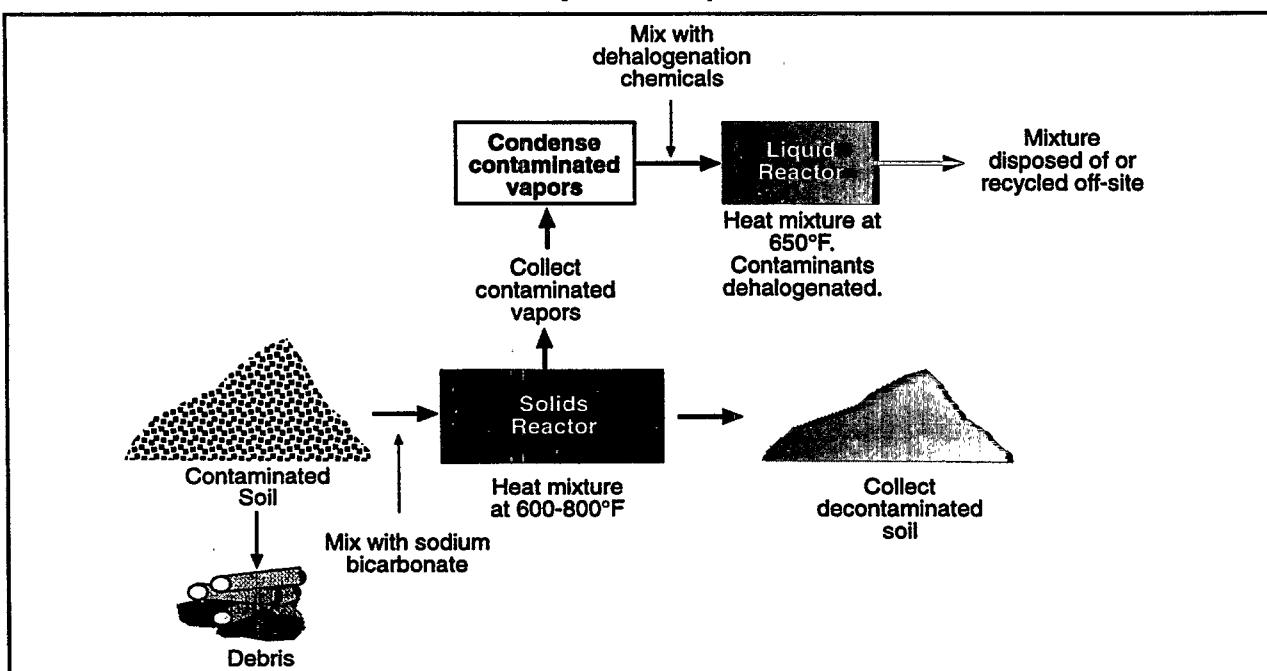


Table 1
Examples of Superfund Sites Using Chemical Dehalogenation*

Name of Site	Status**	Process	Contaminants
Wide Beach Development, NY	Completed	Glycolate dehalogenation	Polychlorinated biphenyls (PCBs)
Myers Property, NJ	In design	BCD	Semi-volatile organic compounds (SVOCs), pesticides
Saunders Supply Co., VA	In design	To be determined	SVOCs, dioxins

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

* Not all waste types and site conditions are comparable. Each site must be individually investigated and tested.

Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

** As of August 1995

For More Information

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Sources*, January 1995, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Physical/Chemical Treatment Technology Resource Guide*, September 1994, EPA 542-B-94-008. A bibliography of publications about chemical dehalogenation and other innovative treatment technologies.
- *Engineering Bulletin: Chemical Dehalogenation Treatment: APEG Treatment*, September 1990, EPA 540-2-90-015.
- *SITE Program Technology Profiles (7th Ed.)*, November 1994, EPA 540-R-94-526.

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Guía del ciudadano: La deshalogenación química

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es la deshalogenación química?

La deshalogenación química es un proceso químico para retirar los *halógenos* (generalmente cloro) de un contaminante químico, volviéndolo menos peligroso. Los *halógenos* son una clase de elementos químicos en la cual se encuentran el cloro, el bromo, el yodo y el flúor. Los bifenilos policlorados son compuestos halogenados que antes se usaban en transformadores eléctricos de alta tensión porque eran buenos conductores del calor y al mismo tiempo eran resistentes al fuego y buenos aisladores eléctricos. Además, los compuestos halogenados se usan para fabricar plaguicidas porque confieren la toxicidad necesaria para combatir plagas. Los compuestos halogenados también se usan comúnmente en el tratamiento del agua, en productos químicos para piscinas, en la fabricación de tuberías de plástico y en la industria textil. La técnica de deshalogenación química puede aplicarse a contaminantes halogenados comunes, como bifenilos policlorados y dioxinas, que generalmente se encuentran en el suelo y en aceites.

¿Cómo funciona?

Se usan dos versiones comunes del proceso de deshalogenación química: la deshalogenación con glicolatos y el proceso de descomposición catalizado por bases.

Deshalogenación con glicolatos

Para la deshalogenación con glicolatos se usa un reactivo químico llamado APEG. El APEG tiene dos

componentes: un hidróxido de metales alcalinos (la "A" de las siglas APEG) y glicol polietilénico (que se abrevia "PEG" en inglés), sustancia similar al anticongelante. El hidróxido de sodio y el hidróxido de potasio son hidróxidos de metales alcalinos comunes. El glicolato polietilénico de potasio es el reactivo APEG más común. El proceso consiste en mezclar y calentar la tierra contaminada con el reactivo APEG. Durante el calentamiento, el hidróxido de metal alcalino reacciona con el halógeno del contaminante, formando una sal que no es tóxica, y el glicol polietilénico ocupa el lugar que antes ocupaba el halógeno en la molécula de bifenilo policlorado, volviéndolo menos peligroso.

El proceso de deshalogenación con glicolatos abarca cinco pasos: preparación, reacción, separación, lavado y deshidratación (figura 1). Durante la preparación, se excavan los desechos contaminados (tierra, por ejemplo) y se pasan por una criba para separar desechos y objetos grandes tales como piedras y troncos. Después, en el paso de reacción, se vierte la tierra contaminada y el reactivo APEG en un contenedor de gran tamaño, llamado *reactor*, donde se mezclan y se calientan durante cuatro horas.

Los vapores que se producen durante el calentamiento se recogen y se separan en agua y contaminantes gaseosos en un condensador. El agua se puede usar en un paso posterior del proceso, en tanto que los contaminantes gaseosos pasan por filtros de carbón activado que capturan el contaminante.

Perfil de la deshalogenación química

- Se usa para tratar contaminantes orgánicos aromáticos halogenados, particularmente bifenilos policlorados y dioxinas.
- Por medios químicos se convierten materiales tóxicos en materiales menos tóxicos o que no son tóxicos.
- Consiste en calentar y mezclar físicamente tierra contaminada con reactivos químicos.
- Esta técnica usa dispositivos portátiles que pueden trasladarse hasta el lugar de las operaciones.

Después del tratamiento en el reactor, la mezcla de tierra y APEG pasa al separador, donde se separa el reactivo APEG de la tierra y se recicla para volver a usarlo en el sistema. La tierra tratada contiene productos del tratamiento que son sustancias menos tóxicas resultantes de la reacción que se produce durante la deshalogenación. Estas sustancias químicas nuevas son una sal que no es tóxica y un compuesto orgánico parcialmente deshalogenado que es menos tóxico.

La tierra pasa del paso de separación a una lavadora, donde se añade el agua recogida en el paso de reacción anterior. Se extraen de la tierra los últimos vestigios del reactivo APEG y se reciclan. La tierra pasa a la etapa de deshidratación, en la cual se separan el agua y la tierra. El agua es sometida a un tratamiento para retirar los contaminantes antes de verterla en un sistema municipal de tratamiento de aguas, un arroyo receptor u otros lugares apropiados para la descarga. La tierra es sometida a otra prueba para determinar la concentración de contaminantes. Si los contaminantes que contiene todavía exceden las metas del tratamiento, vuelve a pasar por el proceso o se coloca en un vertedero que no presente riesgos ambientales; si la tierra está limpia, puede volver a colocarse en el sitio original.

Descomposición catalizada por bases

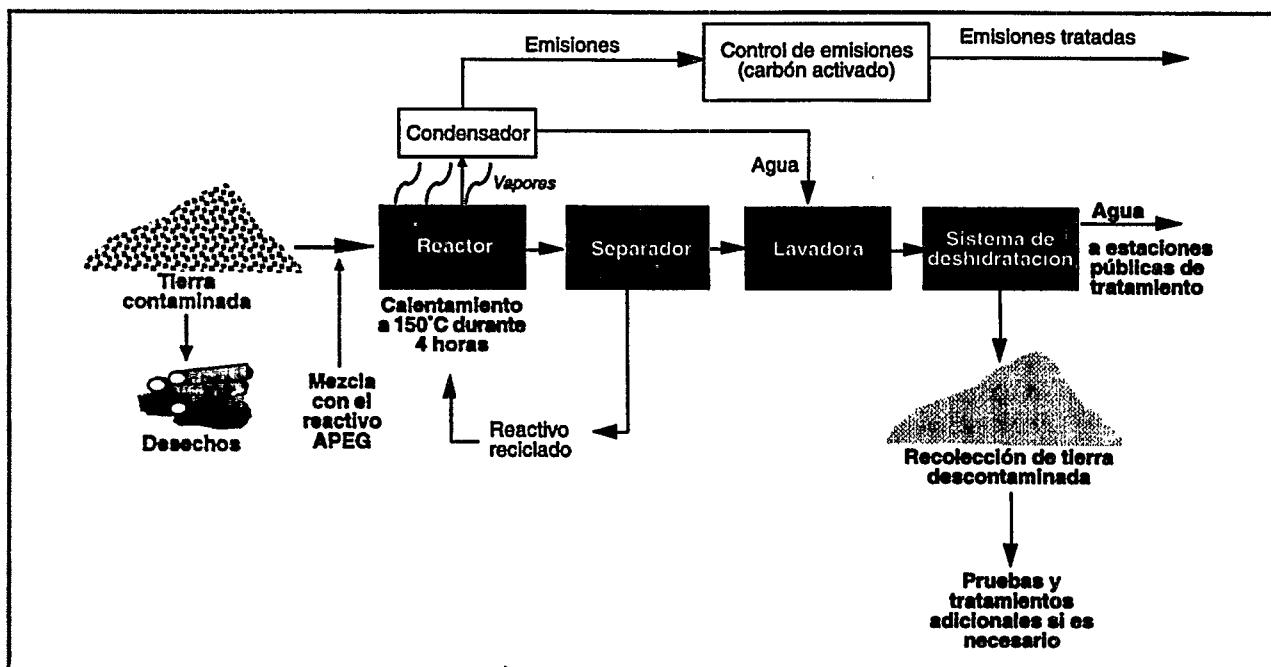
El segundo tipo de deshalogenación química —la descomposición catalizada por bases— fue ideado por el Organismo para la Protección del Medio Ambiente, de Estados Unidos. Es una técnica económica, que no causa contaminación, para corregir el problema de la contaminación

de líquidos, fangos residuales, tierra y sedimentos con compuestos orgánicos clorados, especialmente bifenilos policlorados, plaguicidas, algunos herbicidas y dioxinas.

En el proceso de descomposición catalizada por bases (figura 2 de la página 3), se excava el suelo contaminado y se pasa la tierra por una criba para sacar desechos y partículas grandes, después se tritura y se mezcla con bicarbonato de sodio en una proporción de alrededor de una parte de bicarbonato de sodio por diez partes de tierra. Esta mezcla se calienta en un reactor. El calor separa los compuestos halogenados de la tierra por evaporación. La tierra que queda se saca del reactor y se puede llevar de vuelta a su lugar de origen. Los gases contaminados, condensados en forma líquida, pasan a un reactor de fase líquida. La reacción de deshalogenación se produce cuando varias sustancias químicas, entre ellas hidróxido de sodio (una base), se mezclan con los contaminantes condensados y se calientan en el reactor. La mezcla líquida resultante se puede incinerar o tratar con otra técnica y reciclar. Con la descomposición catalizada por bases no es necesario extraer los reactivos de la tierra tratada como en el caso de la deshalogenación con glicolatos.

Los dispositivos que se usan para la descomposición catalizada por bases se pueden transportar fácilmente y no presentan riesgos. Se usa equipo en existencia, que requiere menos tiempo y espacio para movilizar, instalar y desmantelar que un incinerador, otro tratamiento común de los desechos contaminados con bifenilos policlorados.

Figura 1
El proceso de deshalogenación con glicolatos



¿Qué son las técnicas de tratamiento innovadoras?

Las técnicas de tratamiento son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden alterar materiales contaminados, destruyéndolos o modificándolos, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos. Las técnicas de tratamiento innovadoras son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

¿En qué casos convendría usar la técnica de deshalogenación química?

La deshalogenación puede ser un proceso eficaz para suprimir halógenos de compuestos orgánicos peligrosos, como dioxinas, furanos, bifenilos policlorados y ciertos plaguicidas clorados. El tratamiento dura poco, usa una cantidad moderada de energía y los gastos de operación y mantenimiento son relativamente bajos. Los dispositivos pueden trasladarse hasta el sitio que deba tratarse, de modo que no es necesario transportar desechos peligrosos.

¿Dará resultado la deshalogenación en cualquier lugar?

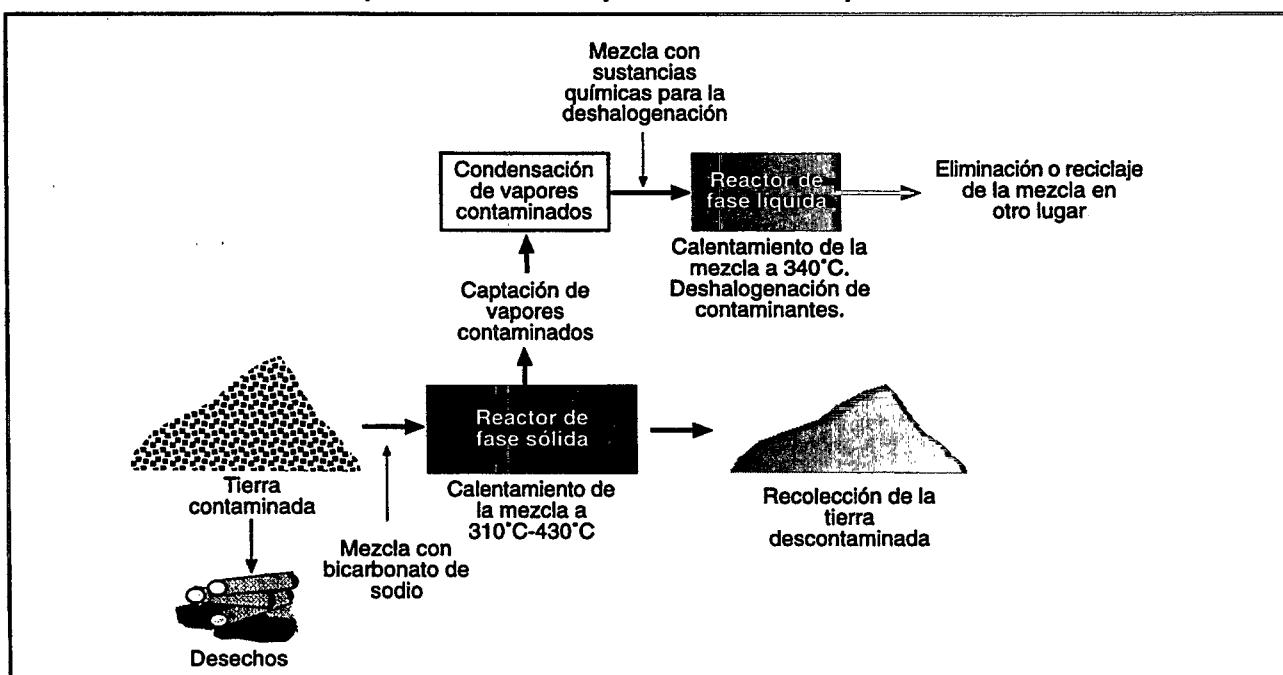
Las características del material contaminado que interfieren en la eficacia de la deshalogenación química son un alto contenido de arcilla o agua, acidez o alto

contenido orgánico natural del suelo. La deshalogenación con glicolatos no sirve para tratar grandes cantidades de desechos o desechos con una concentración de contaminantes clorados superior al 5%. Como es necesario excavar el suelo contaminado y cribar la tierra antes del tratamiento, debe haber suficiente lugar en el sitio para realizar este tratamiento preliminar.

¿Dónde se está usando la deshalogenación?

En el cuadro 1 de la página 4 figuran algunos sitios para los cuales se ha seleccionado la deshalogenación química como método de tratamiento con recursos del *Superfund*. Asimismo, la Armada de Estados Unidos ha usado la descomposición catalizada por bases en un centro de obras públicas de Guam para tratar tierra contaminada con difenilos policlorados. Con esta técnica se alcanzaron las metas de limpieza establecidas por el EPA para el suelo.

Figura 2
El proceso de descomposición catalizado por bases



Cuadro 1
Ejemplos de sitios donde se usa la deshalogenación química con recursos del Superfund*

Nombre del sitio	Situación**	Proceso	Contaminantes
Wide Beach Development (Nueva York)	Concluido	Deshalogenación con glicolatos	Bifenilos policlorados
Myers Property (Nueva Jersey)	En proyecto	Descomposición catalizada por bases	Compuestos orgánicos semivolátiles, plaguicidas
Saunders Supply Co. (Virginia)	En proyecto	Se determinará más adelante	Compuestos orgánicos semivolátiles, dioxinas

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Hay una base de datos con más información sobre los sitios indicados en el Annual Status Report. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en disquetes. Consulte al NCEPI para más pormenores.

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** Hasta agosto de 1995.

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, enero de 1995, EPA 542-B-95-001. Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.
- *Physical/Chemical Treatment Technology Resource Guide*, septiembre de 1994, EPA 542-B-94-008. Bibliografía de publicaciones sobre la deshalogenación química y otras técnicas de tratamiento innovadoras.
- *Engineering Bulletin: Chemical Dehalogenation Treatment: APEG Treatment*, septiembre de 1990, EPA 540-2-90-015.
- *SITE Program Technology Profiles (7th Ed.)*, noviembre de 1994, EPA 540-R-94-526.

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A Citizen's Guide to In Situ Soil Flushing

Technology Innovation Office

Technology Fact Sheet

What is in situ soil flushing?

In situ soil flushing is an innovative treatment technology that floods contaminated soils with a solution that moves the contaminants to an area where they are removed. "In situ"—meaning "in place"—refers to treating the contaminated soil without digging up or removing it.

The specific contaminants in the soil at any particular site determine the type of flushing solution needed in the treatment process. The flushing solution is typically one of two types of fluids: 1) *water only*; or 2) *water plus additives* such as acids (low pH), bases (high pH) or surfactants (like detergents).

Water is used to treat contaminants that dissolve easily in water. An *acidic solution* is a mixture of water and an acid, such as nitric acid or hydrochloric acid. Acidic solutions are used to remove metals and organic contaminants, such as those typically found in battery recycling or industrial chrome plating processes. For example, zinc contamination—which can result from plating operations—would be treated with an acidic solution. A *basic solution* is a mixture of water and a base, such as sodium

hydroxide. (Ammonia is an example of a base commonly used in households.) Basic solutions are used to treat phenols and some metals. A *surfactant* can be a detergent or emulsifier. Emulsifiers help mix substances that normally do not mix such as oil and water. For this reason, surfactant solutions are effective at removing oily contaminants.

Researchers also are investigating the use of water plus *organic solvents* as a flushing solution. Organic solvents such as ethanol are used to dissolve certain contaminants that water alone cannot dissolve.

How does it work?

Figure 1 on page 2 provides an illustration of one type of in situ soil flushing process. The process begins with the drilling of injection wells and extraction wells into the ground where the contamination has been found. The number, location, and depth of the injection and extraction wells depend on many geological factors and engineering considerations. Wells may be installed either vertically or horizontally. In addition to placing the wells, other equipment—such as a wastewater treatment system—must be transported to or built on the site.

A Quick Look at In Situ Soil Flushing

- Injects a washing solution into unexcavated soils to flush out contaminants.
- Is most effective on soils with low silt or clay content.
- Requires the drilling of injection and extraction wells on-site.
- Is a transportable technology that can be brought to the site.
- Requires greater understanding of the site's geology than some other technologies.

The soil flushing equipment pumps the flushing solution into the injection wells. The solution passes through the soil, picking up contaminants along its way as it moves toward the extraction wells. The extraction wells collect the *elutriate*—the flushing solution mixed with the contaminants.

The elutriate is pumped out of the ground through the extraction wells. Here, the elutriate is typically treated by a wastewater treatment system to remove the contaminants. The contaminants are treated or disposed of, and the treated water can either be recycled for use in the flushing solution or disposed of in another acceptable manner. It is because of this circular process that in situ soil flushing systems are often referred to as injection/recirculation systems.

Any contaminated fumes or vapors that might be given off during the wastewater treatment step of the process are collected and treated.

Why consider in situ soil flushing?

In situ soil flushing can be tailored to treat specific contaminants. For example, if a site is contaminated

How Is Soil Flushing Different From Soil Washing?

With soil flushing, the soil is treated in place using an injection/recirculation process. Soil washing involves excavating the contaminated soil and treating it at the surface in a soil washer.

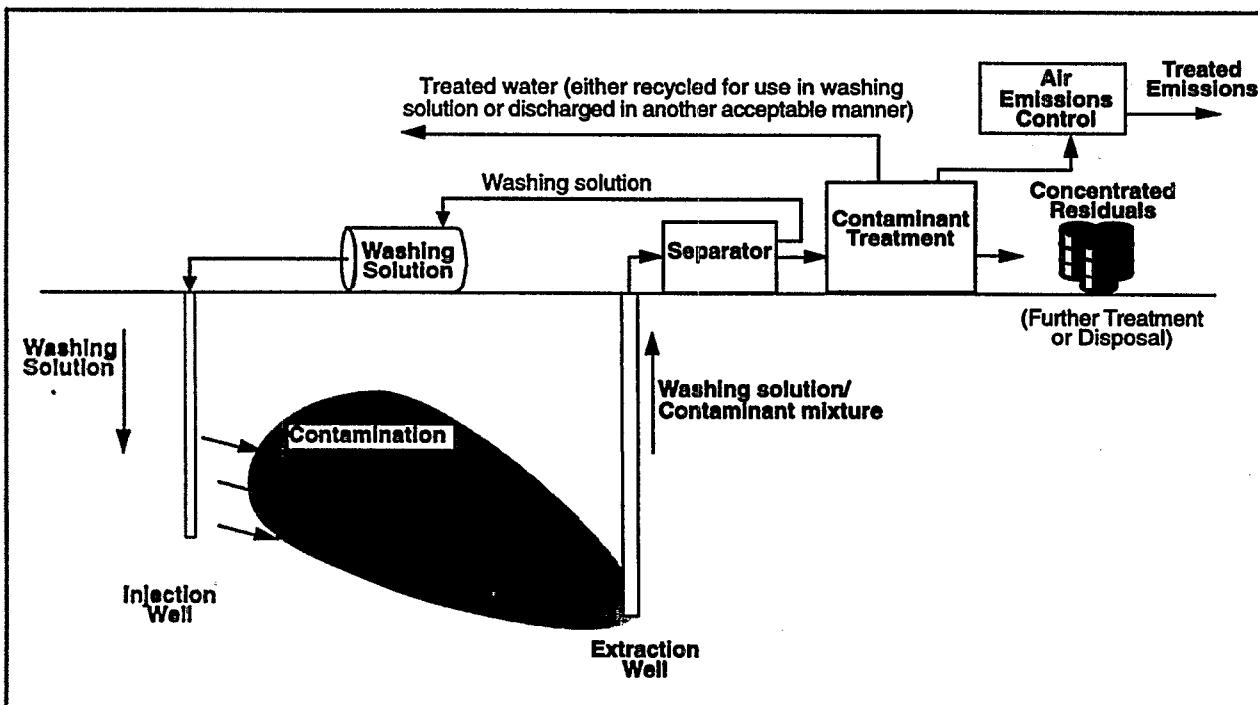
with oily waste, surfactants can be added to the flushing solution to remove them more easily from the soil.

In addition, since soil flushing is conducted in situ, it reduces the need for excavation, handling, or transportation of the hazardous substances. The process has been most effective in removing the contaminants such as those identified in Figure 2 on page 3.

Will it work at every site?

In situ soil flushing works best at sites with soil that has spaces that permit the wash solution to move

Figure 1
The In Situ Soil Flushing Process (Using Vertical Wells)



What Is an Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste.

Innovative treatment technologies are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

- Since *in situ* soil flushing is tailored to treat specific contaminants, it is not highly effective with soils contaminated with a mixture of hazardous substances, for example, metals and oils. It would be difficult to prepare a flushing solution that would effectively remove several different types of contaminants at the same time.

Where is *in situ* soil flushing being used?

Table 1 on page 4 lists some Superfund sites where *in situ* soil flushing has been selected as a treatment method.

Figure 2

Contaminants Considered for Treatment by *In Situ* Soil Flushing

Contaminants	Industries Where Used
Heavy metals (lead, copper, zinc)	Battery Recycling, Metal Plating
Halogenated solvents (TCE, trichloroethane)	Drycleaning, Electronics Assembly
Aromatics (benzene, toluene, cresol, phenol)	Wood Treating
Gasoline and fuel oils	Petroleum, Automobile
PCBs and chlorinated phenol	Pesticide, Herbicide, Electric Power

Not all waste types and site conditions are comparable. Each site must be individually investigated and tested. Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

through it. If the soil has a high percentage of silt or clay, for example, the flushing solution can not easily move through the soil, so it can not easily make contact with the contaminants. This limits the overall effectiveness of the soil flushing process. In addition, some flushing fluids contain additives which may themselves create new groundwater contamination if they are not completely removed.

There are additional considerations for the use of this technology. For example:

- The flow of the groundwater must be well understood in order to design the well system for a given site. Extensive field investigations may be necessary to define the groundwater flow completely.
- The makeup and arrangement of subsurface layers must be well understood to be able to predict the path of the flushing fluids and contaminants and ensure that the contamination is not spread beyond the area from which it can be collected.

Table 1
Examples of Superfund Sites Using Soil Flushing *

Name of Site	Status**	Type of Facility	Contaminants
Lipari Landfill, NJ	Operational	Landfill	Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals
Vineland Chemical, NJ	In design	Pesticide manufacturing	Metals
Ninth Avenue Dump, MI	Completed	Industrial landfill	VOCs, polycyclic aromatic hydrocarbons (PAHs)
Lee Chemical, MO	Operational	Solvent recovery	VOCs
Idaho Pole Company, MT	In design	Wood preserving	SVOCs, PAHs
United Chrome Products, OR	Operational	Chrome plating	Metals
Umatilla Army Depot, OR	Design complete	Explosives storage	Explosives, propellants

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

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**As of August 1995

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Resources*, January 1995, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Physical/Chemical Treatment Technology Resource Guide*, September 1994, EPA 542-B-94-008. A bibliography of publications and other sources of information about soil flushing, soil washing, solvent extraction, and other innovative treatment technologies.
- *Engineering Bulletin: In Situ Soil Flushing*, May 1991, EPA 540-2-91-021.
- *Engineering Issue: Considerations in Deciding to Treat Contaminated Soils In Situ*, EPA 540-S-94-500.
- *In Situ Remediation Technology Status Report: Surfactant Enhancement*, EPA 542-K-94-003.
- *In Situ Remediation Technology Status Report: Cosolvents*, EPA 542-K-94-006.
- WASTECH® Monograph on *Soil Washing/Soil Flushing*, ISBN #1-883767-03-2. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: El enjuague del suelo in situ

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es el enjuague del suelo in situ?

El enjuague del suelo in situ es una técnica de tratamiento innovadora que consiste en inundar suelos contaminados con una solución que lleva los contaminantes hasta un lugar donde pueden extraerse. "In situ" (que significa "en el lugar") se refiere al tratamiento de tierra contaminada sin excavarla ni sacarla de su lugar.

El tipo de solución que se necesita para el tratamiento depende de los contaminantes que se hallen en el suelo en un lugar determinado. La solución de enjuague generalmente es uno de los siguientes líquidos: 1) *agua solamente* o 2) *agua con aditivos* tales como ácidos (pH bajo), bases (pH alto) o agentes tensioactivos (como detergentes).

El *agua* se usa para tratar contaminantes que se disuelven fácilmente en el agua. Una *solución acídica* es una mezcla de agua y ácido, como ácido nítrico o ácido clorhídrico. Las soluciones acídicas se usan para extraer metales y contaminantes orgánicos, como los que se encuentran generalmente en el reciclaje de baterías o en procesos de cromado industrial. Por ejemplo, la contaminación con zinc, una de las

posibles consecuencias de las operaciones de cromado, se trataría con una solución acídica. Una *solución básica* es una mezcla de agua y una base, como hidróxido de sodio. (El amoníaco es un ejemplo de una base que se usa comúnmente en el hogar.) Las soluciones básicas se usan para tratar fenoles y algunos metales. Un *agente tensioactivo* puede ser un detergente o un emulsor. Los emulsores facilitan la mezcla de sustancias que normalmente no se mezclan, como aceite y agua. Por esta razón, las soluciones tensioactivas son eficaces para retirar contaminantes oleosos.

También se está investigando el uso de agua con *solventes orgánicos* como solución de enjuague. Los solventes orgánicos, como el etanol, se usan para disolver ciertos contaminantes que el agua sola no puede disolver.

¿Cómo funciona?

La figura 1 de la página 2 es un esquema de un tipo de enjuague del suelo in situ. El proceso comienza con la perforación de pozos de inyección y de extracción en el suelo contaminado. La cantidad, la ubicación y la profundidad de los pozos de inyección y

Perfil del enjuague de suelos in situ

- Se inyecta una solución de lavado en suelos sin excavar para arrastrar los contaminantes hasta un lugar donde puedan extraerse.
- Es sumamente eficaz para el tratamiento de suelos con bajo contenido de limo o arcilla.
- Requiere la perforación de pozos de inyección y de extracción en el lugar.
- El equipo es portátil y puede llevarse hasta el lugar de las operaciones.
- Exige una mayor comprensión de las características geológicas del sitio que otras técnicas.

de extracción dependen de varios factores geológicos y consideraciones técnicas. Los pozos pueden instalarse en forma vertical u horizontal. Además de la colocación de los pozos, hay que trasladar hasta el sitio otros equipos (como un sistema de tratamiento de aguas residuales) o construirlos in situ.

La solución de enjuague se introduce en los pozos de inyección por bombeo y pasa por el suelo, arrastrando contaminantes mientras se dirige a los pozos de extracción. En los pozos de extracción se recoge el *elutriado*, o sea la solución de enjuague mezclada con los contaminantes.

El elutriado se extrae del suelo por bombeo en los pozos de extracción y generalmente pasa a un sistema de tratamiento de aguas residuales para retirar los contaminantes. Los contaminantes son tratados o eliminados, y el agua tratada puede reutilizarse en la solución de enjuague o eliminarse de otra forma aceptable. Debido a que se trata de un proceso circular, los sistemas de enjuague del suelo in situ a menudo se denominan sistemas de inyección y recirculación.

¿En qué difieren las técnicas de enjuague del suelo y lavado del suelo?

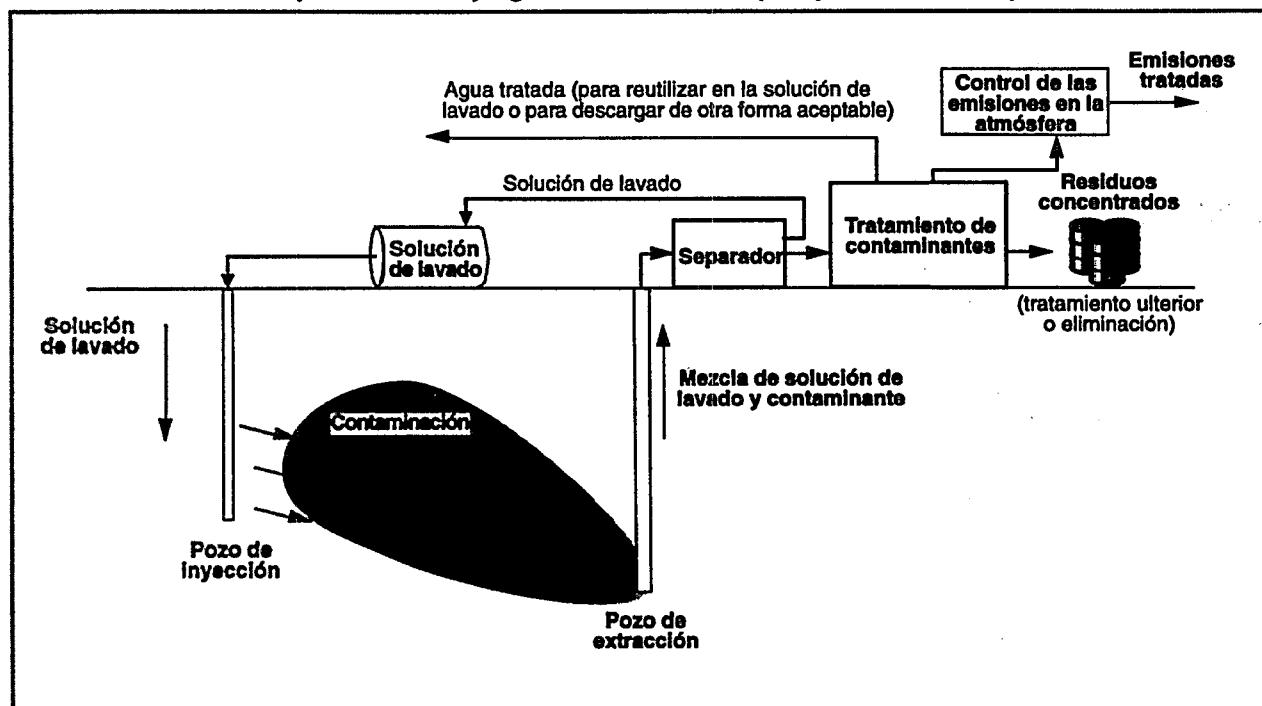
Con el enjuague, el suelo es sometido a un tratamiento in situ con un sistema de inyección y recirculación. El lavado del suelo consiste en excavar el suelo contaminado y tratar la tierra en la superficie en una lavadora de tierra.

El humo o los vapores contaminados que puedan emitirse durante el tratamiento de las aguas residuales se recogen y se someten a un tratamiento.

¿En qué casos convendría usar la técnica de enjuague del suelo in situ?

El enjuague del suelo in situ puede adaptarse al tratamiento de determinados contaminantes. Por ejemplo, si un lugar está contaminado con desechos oleosos, se pueden agregar agentes tensioactivos a la solución de enjuague para facilitar su remoción del suelo.

Figura 1
El proceso del enjuague del suelo in situ (con pozos verticales)



Cuadro 1

Ejemplos de lugares donde se usa la técnica de enjuague del suelo con recursos del Superfund**

Nombre del sitio	Situación**	Tipo de instalación	Contaminantes
Lipari Landfill (Nueva Jersey)	En ejecución	Vertedero	Compuestos orgánicos volátiles, compuestos orgánicos semivolátiles, metales
Vineland Chemical (Nueva Jersey) Ninth Avenue Dump (Michigan)	En proyecto Concluido	Fabricación de plaguicidas Vertedero industrial	Metales Compuestos orgánicos volátiles, hidrocarburos poliaromáticos
Lee Chemical (Misuri) Idaho Pole Company (Montana)	En ejecución En proyecto	Recuperación de solventes Conservación de maderas	Compuestos orgánicos volátiles Compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos
United Chrome Products (Oregón) Umatilla Army Depot (Oregón)	En ejecución Proyecto concluido	Cromado Almacenamiento de explosivos	Metales Explosivos, propulsantes

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Hay una base de datos con más información sobre los sitios indicados en el *Annual Status Report*. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discetes. Consulte al NCEPI para más pormenores.

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** Hasta agosto de 1995.

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- *Physical/Chemical Treatment Technology Resource Guide*, septiembre de 1994, EPA 542-B-94-008. **Bibliografía de publicaciones y otras fuentes de información sobre el enjuague del suelo in situ, el lavado del suelo, la extracción con solventes y otras técnicas de tratamiento innovadoras.**
- *Engineering Bulletin: In Situ Soil Flushing*, mayo de 1991, EPA 540-2-91-021.
- *Engineering Issue: Considerations in Deciding to Treat Contaminated Soils In Situ*, EPA 540-S-94-500.
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¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden alterar materiales contaminados, destruyéndolos o modificándolos, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos.

Las *técnicas de tratamiento innovadoras* son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Además, como el enjuague del suelo se realiza *in situ*, se reduce la necesidad de excavación, movimiento o transporte de las sustancias peligrosas. El proceso ha resultado sumamente eficaz para retirar contaminantes tales como los que se indican en la figura 2 de la página 3.

¿Dará resultado esta técnica en cualquier lugar?

Con el enjuague del suelo *in situ* se obtienen resultados óptimos en lugares donde hay espacios en el suelo que permiten el paso de la solución de lavado. Si el suelo tiene un alto porcentaje de limo o arcilla, por ejemplo, la solución de enjuague no puede desplazarse fácilmente en su interior, de modo que no puede entrar en contacto fácilmente con los contaminantes. Eso limita la eficacia general del proceso de enjuague del suelo. Además, algunos líquidos de enjuague contienen aditivos que podrían contaminar el agua subterránea si no se retiran por completo.

En la selección de esta técnica influyen también los siguientes factores, entre otros:

- Se debe comprender bien el flujo del agua subterránea a fin de proyectar el sistema de pozos para un

lugar determinado. Posiblemente se necesiten extensos estudios sobre el terreno para lograr un conocimiento acabado del flujo del agua subterránea.

- Es necesario comprender bien la composición y disposición de las capas subterráneas para prever el trayecto que seguirán el líquido de enjuague y los contaminantes y cerciorarse de que los contaminantes no se extiendan fuera del lugar donde se pueden recoger.
- Como el enjuague del suelo *in situ* se adapta al tratamiento de determinados contaminantes, no es muy eficaz para los suelos contaminados con una mezcla de sustancias peligrosas, como metales y aceites. Sería difícil preparar una solución de enjuague capaz de retirar eficazmente varios tipos diferentes de contaminantes al mismo tiempo.

¿Dónde se está usando el enjuague del suelo *in situ*?

En el cuadro 1 de la página 4 figuran algunos lugares para los cuales se ha seleccionado el enjuague del suelo *in situ* como método de tratamiento con recursos del *Superfund*.

Figura 2
Contaminantes que podrían tratarse con la técnica de enjuague del suelo *in situ*

Contaminantes	Industrias donde se usa
Metales pesados (plomo, cobre, zinc)	Reciclaje de baterías, revestimientos metálicos
Solventes halogenados (tricloroetano)	Limpieza en seco, ensamblaje de aparatos electrónicos
Aromáticos (benceno, tolueno, cresol, fenol)	Tratamiento de maderas
Gasolina y fuel-oil	Petróleo, automóviles
Bifenilos policlorados y fenol clorado	Plaguicidas, herbicidas, energía eléctrica

No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.



A Citizen's Guide to Innovative Treatment Technologies

For Contaminated Soils, Sludges, Sediments, and Debris

Technology Innovation Office

Technology Fact Sheet

What are innovative treatment technologies?

Treatment technologies are chemical, biological, or physical processes applied to hazardous waste or contaminated materials to permanently change their condition. This Citizen's Guide focuses on treatment technologies for soil, sludge, sediment, and debris.

Treatment technologies destroy contaminants or change them so that they are no longer hazardous or, at least, are less hazardous. They may reduce the amount of contaminated material at a site, remove the component of the waste that makes it hazardous, or immobilize the contaminant within the waste.

Innovative treatment technologies are newly invented processes that have been tested and used as treatments for hazardous waste or other contaminated materials, but still lack enough information about their cost and how well they work to predict their performance under a variety of operating conditions.

Why use an innovative technology?

Treatment of contaminated sludges and soils is a field of technology that has developed and grown since Congress passed the "Superfund" law for contaminated waste site cleanup in 1980. An initial approach to eliminate a hazardous waste from a particular location was to move it somewhere else, or cover it with a cap. These methods

use *land disposal* as the solution to the problem. With an increasing number of cleanups underway, and the passage of amendments to the Superfund law in 1986 that stated a preference for *treatment*, demand developed for alternatives to land disposal that provided more permanent and less costly solutions for dealing with contaminated materials. Development and use of more suitable treatment technologies has progressed.

As knowledge about the cleanup of contaminated sites increases, new methods for more effective, permanent cleanups will become available. Innovative treatment technologies, which lack a long history of full-scale use, do not have the extensive documentation necessary to make them a standard choice in the engineering/scientific community. However, many innovative technologies have been used successfully at contaminated sites in the United States, Canada, and Europe despite incomplete verification of their utility. Some of the technologies were developed in response to hazardous waste problems and some have been adapted from other industrial uses.

Developing and perfecting treatment technologies is an on-going process, as shown in Figure 1 on page 2. The process begins with a **concept** — an idea of how to treat a particular hazardous waste. The concept usually undergoes a research and evaluation process to prove its feasibility. If the concept is found to be useful, often the next step is to undergo bench-scale testing. During bench-scale testing, a small-scale version of the technology is

Why Use Innovative Treatment Technologies?

- They offer cost-effective, long-term solutions to hazardous waste clean-up problems.
- They provide alternatives to land disposal or incineration.
- They are often more acceptable to surrounding communities than some established treatment technologies.

Are Innovative Treatment Technologies Always the Right Choice?

Although innovative treatment technologies may be less expensive and even more effective than established technologies, science and engineering professionals must determine which technology is most appropriate at a given site.

built and tested in a laboratory. During this testing, it is considered an emerging technology. If it is successful during bench-scale testing, it is then demonstrated at small-scale levels at field sites. If successful at the field demonstrations, the technology often will be used full-scale at contaminated waste sites. As the technology is used and evaluated at different sites, it is continuously improved.

Only after a technology has been used at many different types of sites and the results fully documented, is it considered an established technology. The majority of technologies in use today are still classified as innovative.

What types of treatment technologies are in use?

Established technologies such as incineration and solidification/stabilization have been the most widely used at Superfund sites. By 1990, however, 40 percent of the treatment technologies used were innovative. In 1994 the figure reached almost 60 percent. Table 1 on page 3 describes some of the most frequently used innovative treatment technologies.

How is a treatment technology selected for a site?

Before a treatment technology can be selected for a Superfund site, detailed information about the site conditions and contaminants must be collected. EPA uses this information to determine which of the possible remedies will be capable of meeting the clean-up standards that EPA has set.

A treatability study is often conducted to assess a treatment technology's potential for success. It is conducted on contaminated material from the site, either when the treatment technology is being considered or after selection of the remedy, in order to collect additional operation and performance information.

There are three levels of a treatability study. The level chosen depends on the information available about the site and technology and the nature of information that is needed. The quickest, least expensive treatability study is the **laboratory screening**. It is done to learn more about the characteristics of the waste to determine if it would be treatable by a particular technology. A laboratory screening test takes a matter of days and generally costs from \$10,000 to \$50,000. Successful laboratory screening may lead to more sophisticated treatability studies.

The next level of a treatability study is the **bench-scale** study which provides greater information on the performance (and, in some cases, the cost) of a technology by simulating the treatment process using a very small quantity of waste. The objective of this type of test is to determine if the technology can meet the clean-up standards set for the site. These tests typically cost between \$50,000 and \$250,000.

At the highest level, the **pilot-scale treatability study** is usually conducted in the field or the laboratory and requires installation of the treatment technology. This study is used to provide performance, cost, and design objectives for the treatment technology. Due to the cost of this type of study—generally more than \$250,000—it is used almost exclusively to fine-tune the design of the technology following other treatability studies.

What happens if a technology does not work?

There is always a possibility that a treatment technology, established or innovative, may not work once it is in full-scale operation in spite of the best engineering design. Site conditions that could not be predicted from the smaller-scale studies are often to blame. Natural conditions are far more complex than laboratory conditions.

Figure 1
Developing Treatment Technologies

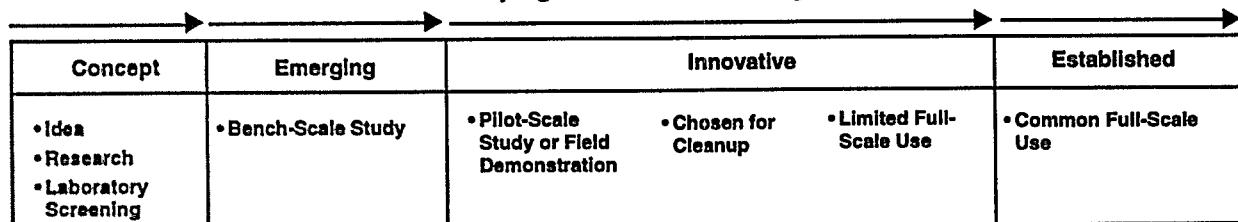


Table 1
Descriptions of Some Innovative Treatment Technologies

Soil Vapor Extraction removes contaminant vapors from soil (without having to dig it up) through the use of vacuum extraction wells placed in the ground. Contaminants are collected for further treatment.

Air Sparging injects air into the ground below the contaminated area, forming bubbles that rise and carry trapped and dissolved contaminants to the surface where they are captured by a soil vapor extraction system.

Bioremediation uses microorganisms, such as bacteria in engineered processes, to break down organic contaminants into harmless substances.

Thermal Desorption heats soil at relatively low temperatures to vaporize contaminants with low boiling points. Vaporized contaminants then are captured and removed for further treatment or destruction.

Soil Washing uses water or a washing solution and mechanical processes to scrub excavated soils and remove hazardous contaminants.

Chemical Dehalogenation converts contaminants that contain halogens (chlorine and fluorine, for example) to less toxic substances through controlled chemical reactions that remove or replace halogen atoms.

Solvent Extraction separates hazardous organic contaminants from oily-type wastes, soils, sludges, and sediments, reducing the volume of hazardous waste that must be treated.

In Situ Soil Flushing floods contaminated soils beneath the ground surface with a solution that flushes the contaminants to an area where they can be extracted.

A technology may be adapted or redesigned to treat targeted waste, despite initial failures. In some rare cases a different technology may have to be designed and installed. Experience with and increasing use of innovative treatment technologies will lead to better and faster ways to clean up the environment.

Where are innovative treatment technologies being selected?

Industry is using technologies labeled as "innovative" by EPA for containing and treating the hazardous wastes generated during manufacturing processes. Innovative technologies also are being used under many federal and state clean-up programs to treat hazardous wastes that have been improperly released on the land. For example, innovative technologies are being selected to manage contamination (primarily petroleum) at some leaking underground tank sites. They also are being selected to clean up contamination that resulted from past disposal practices at industrial sites regulated under the Resource Conservation and Recovery Act, and to clean up contamination at uncontrolled hazardous wastes sites, known as Superfund sites. One innovative treatment technology, soil vapor extraction, is now routinely used in federal and state clean-up programs. As more cost and

performance data are documented, innovative treatment technologies will be increasingly recognized for their effectiveness.

Why is EPA encouraging the use of innovative treatment technologies?

The Environmental Protection Agency is encouraging the selection of innovative treatment technologies for site remedies because they have the potential to be more cost-effective and to provide better and more efficient cleanups. In addition, they are often more acceptable to surrounding communities than established treatment technologies.

EPA Supports the Use of Innovative Treatment Technologies

The mission of EPA's Technology Innovation Office (TIO) is to increase government and industry use of innovative treatment technologies at contaminated waste sites.

Numerous other efforts to increase the use of innovative technologies are described in the EPA fact sheet entitled *Progress in Reducing Impediments to the Use of Innovative Remediation Technology*. (The document number is EPA 542-F-95-008 and can be ordered from NCEPI at the address given below.)

For More Information

The U.S. EPA's Technology Innovation Office has produced a series of Citizen's Guides, including this one, on topics relating to innovative treatment technologies:

- *A Citizen's Guide to Soil Washing*, EPA 542-F-96-002
- *A Citizen's Guide to Solvent Extraction*, EPA 542-F-96-003
- *A Citizen's Guide to Chemical Dehalogenation*, EPA 542-F-96-004
- *A Citizen's Guide to Thermal Desorption*, EPA 542-F-96-005
- *A Citizen's Guide to In Situ Soil Flushing*, EPA 542-F-96-006
- *A Citizen's Guide to Bioremediation*, EPA 542-F-96-007
- *A Citizen's Guide to Soil Vapor Extraction and Air Sparging*, EPA 542-F-96-008
- *A Citizen's Guide to Phytoremediation*, EPA 542-F-96-014
- *A Citizen's Guide to Natural Attenuation*, EPA 542-F-96-015
- *A Citizen's Guide to Treatment Walls*, EPA 542-F-96-016

Some other publications of interest include:

- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Resources*, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. A description of sites at which innovative treatment technologies have been used or selected for use.
- *Innovative Treatment Technologies: Annual Status Report Database*. An automated computer database of descriptions of sites at which innovative treatment technologies have been used or selected for use. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

Copies of the items listed above are available from:

National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242
Fax your order request to 513-489-8695 or call 513-489-8190

If these documents are out of stock, you may be directed to other sources. In this case, there may be a charge for some of these documents.

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Guía del ciudadano: Técnicas de tratamiento innovadoras

Para suelos contaminados, fango residual, sedimentos y detritos

Oficina de Innovaciones

Ficha tecnológica

¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* consisten en la aplicación de procesos químicos, biológicos o físicos a desechos peligrosos o materiales contaminados a fin de cambiar su estado en forma permanente. Esta Guía del ciudadano se concentra en técnicas de tratamiento para suelos, fango residual, sedimentos y detritos.

Las técnicas de tratamiento destruyen contaminantes o los modifican a fin de que dejen de ser peligrosos o, por lo menos, para que sean menos peligrosos. Pueden reducir la cantidad de material contaminado presente en un lugar, retirar el componente de los desechos que los hace peligrosos o inmovilizar el contaminante en los desechos.

Las *técnicas de tratamiento innovadoras* son procedimientos inventados hace poco que se han probado y usado para el tratamiento de desechos peligrosos o de otros materiales contaminados, pero sobre cuyo costo y eficacia todavía no se dispone de suficiente información como para prever los resultados que darán en diversas condiciones de aplicación.

¿Por qué conviene usar técnicas innovadoras?

El tratamiento de fangos residuales y suelos contaminados es un campo de la tecnología que se ha desarrollado y crecido desde 1980, año en que el Congreso aprobó la ley del *Superfund* para la limpieza de sitios con desechos

contaminados. Uno de los métodos iniciales para eliminar un desecho peligroso de un lugar era trasladarlo a otro lugar o cubrirlo. Estos métodos utilizan *vertederos* para solucionar el problema. Con el número creciente de procedimientos de limpieza iniciados y la aprobación de enmiendas a la ley del *Superfund* en 1986 que dan preferencia al *tratamiento*, se planteó la necesidad de otros métodos, que no fuesen el uso de vertederos, para solucionar de forma más permanente y menos costosa el problema de los materiales contaminados. En consecuencia, se ha avanzado en el desarrollo y el uso de técnicas de tratamiento más apropiadas.

A medida que se vayan adquiriendo más conocimientos sobre la limpieza de lugares contaminados, se idearán nuevos métodos para realizar una limpieza más eficaz y permanente. Las técnicas de tratamiento innovadoras carecen de una larga trayectoria de uso en gran escala y no se dispone de la extensa documentación necesaria para convertirlas en una opción corriente en los ámbitos técnicos y científicos. Sin embargo, en sitios contaminados de Estados Unidos, Canadá y Europa se han usado muchas técnicas innovadoras, con buenos resultados, a pesar de que se había realizado sólo una verificación incompleta de su utilidad. Algunas de esas técnicas se idearon para abordar problemas de desechos peligrosos; otras han sido adaptadas de otros usos industriales.

El desarrollo y perfeccionamiento de técnicas de tratamiento es un proceso permanente, como se indica en

¿Por qué conviene usar técnicas de tratamiento innovadoras?

- Ofrecen soluciones a largo plazo y eficaces en función del costo para los problemas de la limpieza de desechos peligrosos.
- Presentan alternativas frente al uso de vertederos y la incineración.
- A menudo son más aceptables para los vecindarios de los alrededores que algunas técnicas de tratamiento habituales.

¿Son las técnicas de tratamiento innovadoras siempre la opción acertada?

Aunque las técnicas de tratamiento innovadoras podrían ser menos costosas e incluso más eficaces que las técnicas consagradas por el uso, los científicos y los técnicos deben determinar qué técnica es la más apropiada para un lugar determinado.

la figura 1 de la página 2. El proceso comienza con un **concepto**, una idea de cómo tratar un desecho peligroso en particular. El concepto generalmente pasa por un proceso de investigación y evaluación para comprobar su factibilidad. Si se llega a la conclusión de que el concepto es útil, el paso siguiente consiste a menudo en pruebas de la técnica en pequeña escala en un laboratorio. Durante esta etapa, la técnica es aún incipiente. Si da resultado en las pruebas de laboratorio, se ensaya en pequeña escala sobre el terreno. Si en esas condiciones también da resultado, con frecuencia la técnica pasa a usarse en gran escala en lugares con desechos contaminados, y se mejora continuamente a medida que se va usando y evaluando en distintos sitios.

Sólo después que una técnica se ha usado en muchos tipos de lugares y que se han documentado plenamente los resultados, se considera que es una técnica consagrada por el uso. La mayoría de las técnicas que usamos en la actualidad todavía están clasificadas como innovadoras.

¿Qué clases de técnicas de tratamiento se usan en la actualidad?

Ciertas técnicas consagradas por el uso, como la incineración y la solidificación/estabilización, son las que más se han usado para operaciones de limpieza con recursos del Superfund. Sin embargo, para 1990, 40% de las técnicas de tratamiento que se estaban usando eran innovadoras. En 1994 esa cifra llegó casi al 60%. En el cuadro 1 de la página 3 se describen algunas de las técnicas de tratamiento innovadoras de uso más frecuente.

¿Cómo se selecciona la técnica de tratamiento para un sitio?

Antes de seleccionar una técnica de tratamiento para operaciones de limpieza de un sitio determinado con recursos del *Superfund*, es necesario recopilar información detallada sobre el estado del lugar y los contaminantes. Basándose en esta información, el EPA determina con cuál de los medios disponibles se podrán cumplir las normas para la limpieza establecidas por el EPA.

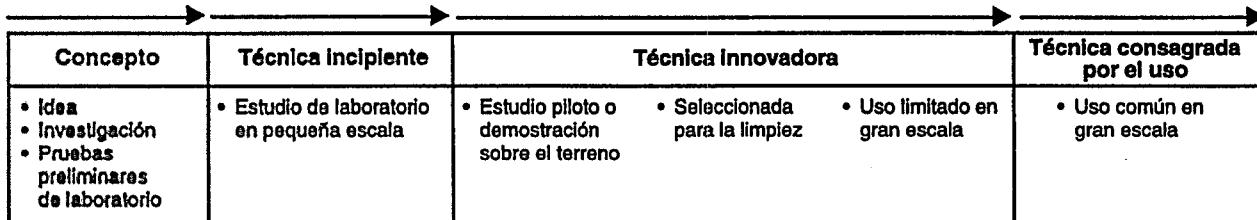
A menudo se hace un estudio de tratabilidad para determinar las posibilidades de éxito de una técnica de tratamiento. Este estudio se hace con materiales contaminados extraídos del sitio, cuando se está considerando la posibilidad de usar una técnica o después de seleccionarla, para obtener información adicional sobre su acción y su eficacia.

Hay tres niveles de estudios de tratabilidad. El nivel que se seleccione dependerá de la información disponible sobre el sitio y de la tecnología y el tipo de información que se necesiten. El estudio de tratabilidad más rápido y económico es una **prueba preliminar de laboratorio**, que se hace con el propósito de obtener más información sobre las características de los desechos a fin de determinar si podrían tratarse con una técnica determinada. Una prueba preliminar de laboratorio se puede hacer en cuestión de días y generalmente cuesta entre US\$10.000 y US\$50.000. Si se obtienen buenos resultados, se podrían realizar estudios de tratabilidad más avanzados.

El nivel siguiente en los estudios de tratabilidad es la **prueba de laboratorio en pequeña escala**, que consiste en simular un proceso de tratamiento con una cantidad muy pequeña de desechos y proporciona más información sobre la eficacia (y, en algunos casos, sobre el costo) de una técnica. El objetivo de las pruebas de este tipo es determinar si con la técnica se podrán cumplir las normas para la limpieza del sitio. El costo de estas pruebas generalmente se sitúa entre US\$50.000 y US\$250.000.

El nivel más alto es el **estudio piloto de tratabilidad**, que generalmente se hace sobre el terreno o en el laboratorio y requiere la instalación de equipo de tratamiento. Este estudio se usa para establecer objetivos de eficacia, costo y

Figura 1
Desarrollo de técnicas de tratamiento



Cuadro 1
Descripción de algunas técnicas de tratamiento innovadoras

Extracción de vapores del suelo: remoción de vapores contaminantes del suelo (sin excavar) mediante pozos de aspiración. Se recogen los contaminantes para someterlos a un tratamiento ulterior.

Aspersión de aire: inyección de aire en el suelo debajo de la zona contaminada; el aire forma burbujas que suben, llevando contaminantes atrapados y disueltos hasta la superficie, donde se pueden capturar con un sistema de extracción de vapores del suelo.

Medidas biocorrectivas: uso de microorganismos, como bacterias en procesos manejados, para descomponer contaminantes orgánicos en sustancias inocuas.

Desorción térmica: calentamiento del suelo a temperaturas relativamente bajas para vaporizar contaminantes con un punto de ebullición bajo. Los contaminantes vaporizados se capturan y se retiran para someterlos a un tratamiento ulterior o para destruirlos.

Lavado del suelo: uso de agua o de una solución de lavado y procedimientos mecánicos para depurar suelos excavados y retirar contaminantes peligrosos.

Deshalogenación química: conversión de contaminantes que contienen halógenos (cloro y flúor, por ejemplo) en sustancias menos tóxicas mediante reacciones químicas controladas que retiran o reemplazan los átomos de halógenos.

Extracción con solventes: separación de contaminantes orgánicos peligrosos de desechos oleosos, suelos, fango residual y sedimentos, reduciendo la cantidad de desechos peligrosos que deben tratarse.

Enjuague del suelo in situ: inundación subterránea de suelos contaminados con una solución que arrastra los contaminantes hasta un lugar donde pueden extraerse.

concepción para la técnica de tratamiento. Debido a su costo, que generalmente supera los US\$250.000, se usa casi exclusivamente para perfeccionar la concepción de la técnica después de otros estudios de tratabilidad.

¿Qué pasa si una técnica no da resultado?

Siempre existe la posibilidad de que una técnica de tratamiento, consagrada por el uso o innovadora, no dé resultado cuando comienza a aplicarse en gran escala, a pesar de que la concepción técnica sea óptima. A menudo el problema se debe a condiciones del sitio que no podían preverse en estudios en menor escala. Las condiciones naturales son mucho más complejas que las condiciones de laboratorio.

A pesar de un fracaso inicial, se puede adaptar o modificar una técnica para tratar desechos en forma selectiva. Rara vez será necesario idear y aplicar una técnica diferente. La experiencia que se adquiera con el uso creciente de técnicas de tratamiento innovadoras conducirá a métodos de limpieza ambiental más rápidos y mejores.

¿Dónde se seleccionan las técnicas de tratamiento innovadoras?

La industria está usando técnicas consideradas "innovadoras" por el EPA para contener y tratar los desechos peligrosos generados en procesos de fabricación.

También se están usando técnicas innovadoras en muchos programas de limpieza federales y estatales para tratar desechos peligrosos que han sido liberados indebidamente en la tierra. Por ejemplo, se están seleccionando técnicas innovadoras para manejar la contaminación (principalmente con petróleo) causada por fugas de tanques subterráneos. Otros usos son la descontaminación de sitios industriales reglamentados por la Ley de Conservación y Recuperación de Recursos que se contaminaron debido a métodos de eliminación que se usaban antes, así como la descontaminación de lugares que no están sujetos a control, conocidos como "sitios del Superfund". La extracción de vapores del suelo es una técnica de tratamiento innovadora que ahora se usa regularmente en programas de limpieza federales y estatales. A medida que se obtengan más datos sobre su costo y rendimiento, se reconocerá la eficacia de las técnicas de tratamiento innovadoras.

¿Por qué promueve el EPA el uso de técnicas de tratamiento innovadoras?

El Organismo de Protección Ambiental promueve la selección de técnicas de tratamiento innovadoras para corregir la situación en muchos lugares porque podrían resultar más eficaces en función del costo y permitir una limpieza mejor y más eficiente. Además, con frecuencia son más aceptables para los vecindarios de los alrededores que las técnicas de tratamiento habituales.

El EPA apoya el uso de técnicas de tratamiento innovadoras

La misión de la Oficina de Innovaciones Tecnológicas (TIO) del EPA es promover el uso de técnicas de tratamiento innovadoras por el gobierno y la industria en lugares donde hay desechos contaminados.

En la ficha tecnológica del EPA titulada *Progress in Reducing Impediments to the Use of Innovative Remediation Technology* se describen muchas otras medidas para promover el uso de técnicas innovadoras. (El número de esta publicación es EPA-542-F-95-008; envíe su pedido al NCEPI, cuya dirección figura más abajo.)

Para más información:

La Oficina de Innovaciones Tecnológicas del EPA ha publicado una serie de Guías del ciudadano, incluida la presente, sobre temas relacionados con técnicas de tratamiento innovadoras:

- **Guía del ciudadano: El lavado del suelo, EPA 542-F-96-018**
- **Guía del ciudadano: La extracción con solventes, EPA 542-F-96-019**
- **Guía del ciudadano: La deshalogenación química, EPA 542-F-96-020**
- **Guía del ciudadano: La desorción térmica, EPA 542-F-96-021**
- **Guía del ciudadano: El enjuague del suelo in situ, EPA 542-F-96-022**
- **Guía del ciudadano: Medidas biocorrectivas, EPA 542-F-96-023**
- **Guía del ciudadano: La extracción de vapores del suelo y la aspersión de aire, EPA 542-F-96-024**
- **Guía del ciudadano: Medidas fitocorrectivas, EPA 542-F-96-025**
- **Guía del ciudadano: Atenuación natural, EPA 542-F-96-026**
- **Guía del ciudadano: Muros de tratamiento, EPA 542-F-96-027**

Otras publicaciones de interés:

- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Resources, EPA 542-B-95-001.* **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- *Innovative Treatment Technologies: Annual Status Report (7th Ed.), EPA 542-R-95-008.* **Descripción de lugares donde se han usado técnicas de tratamiento innovadoras o para los cuales se han seleccionado técnicas de este tipo.**
- *Innovative Treatment Technologies: Annual Status Report Database.* **Base de datos computadorizada automática con la descripción de lugares donde se han usado técnicas de tratamiento innovadoras o para los cuales se han seleccionado técnicas de este tipo.** La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en disquetes. Consulte al NCEPI para más pormenores.

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A Citizen's Guide to Natural Attenuation

Technology Innovation Office

Technology Fact Sheet

What is natural attenuation?

Natural attenuation makes use of natural processes to contain the spread of contamination from chemical spills and reduce the concentration and amount of pollutants at contaminated sites. Natural attenuation—also referred to as *intrinsic remediation*, *bioattenuation*, or *intrinsic bioremediation*—is an *in situ* treatment method. This means that environmental contaminants are left in place while natural attenuation works on them. Natural attenuation is often used as one part of a site cleanup that also includes the control or removal of the source of the contamination.

How does natural attenuation work?

The processes contributing to natural attenuation are typically acting at many sites, but at varying rates and degrees of effectiveness, depending on the types of contaminants present, and the physical, chemical and biological characteristics of the soil and ground water. Natural attenuation processes are often categorized as *destructive* or *non-destructive*. Destructive processes destroy the contaminant.

Non-destructive processes do not destroy the contaminant but cause a reduction in contaminant concentrations.

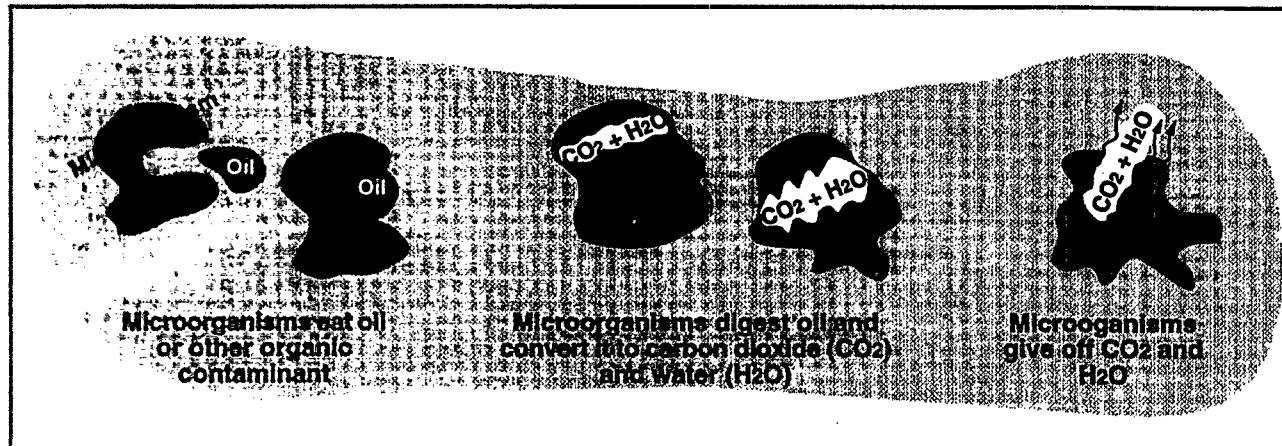
Natural attenuation processes may reduce contaminant mass (through destructive processes such as **biodegradation** and chemical transformations); reduce contaminant concentrations (through simple **dilution** or **dispersion**); or bind contaminants to soil particles so the contamination does not spread or migrate very far (**adsorption**).

Biodegradation, also called bioremediation, is a process in which naturally occurring microorganisms (yeast, fungi, or bacteria) break down, or *degrade*, hazardous substances into less toxic or nontoxic substances. Microorganisms, like humans, eat and digest organic substances for nutrition and energy. (In chemical terms, “organic” compounds are those that contain carbon and hydrogen atoms.) Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans. Biodegradation can occur in the presence of oxygen (aerobic conditions) or without oxygen (anaerobic conditions). In most subsurface environments, both aerobic and anaerobic biodegradation of contaminants occur. The microorganisms break down the organic contaminants into harmless products—mainly carbon dioxide and water in the case of aerobic biodegradation (Figure 1). Once the contaminants are degraded, the

A Quick Look at Natural Attenuation

- Uses naturally occurring environmental processes to clean up sites.
- Is non-invasive and allows the site to be put to productive use while being cleaned up.
- Requires careful study of site conditions and monitoring of contaminant levels.

Figure 1. Schematic Diagram of Aerobic Biodegradation in Soil



microorganism populations decline because they have used their food sources. Dead microorganisms or small populations in the absence of food pose no contamination risk. The fact sheet entitled *A Citizen's Guide to Bioremediation* describes the process in detail (see page 4).

Many organic contaminants, like petroleum, can be biodegraded by microorganisms in the underground environment. For example, biodegradation processes can effectively cleanse soil and ground water of hydrocarbon fuels such as gasoline and the BTEX compounds—benzene, toluene, ethylbenzene, and xylenes. Biodegradation also can break down chlorinated solvents, like trichloroethylene (TCE), in ground water but the processes involved are harder to predict and are effective at a smaller percentage of sites compared to petroleum-contaminated sites. Chlorinated solvents, widely used for degreasing aircraft engines, automobile parts, and electronic components, are among the most often-found organic ground-water contaminants. When chlorinated compounds are biodegraded, it is important that the degradation be complete, because some products of the breakdown process can be more toxic than the original compounds.

The effects of dilution and dispersion appear to reduce contaminant concentration but do not destroy the contaminant. Relatively clean water from the ground surface can seep underground to mix with and dilute contaminated ground water. Clean ground water from an underground location flowing into

contaminated areas, or the dispersion of pollutants as they spreading out away from the main path of the contaminated plume also lead to a reduced concentration of the contaminant in a given area.

Adsorption occurs when contaminants attach or *sorb* to underground particles. Fuel hydrocarbons tend to repel water, as most oily substances do. When they have an opportunity to escape from the ground water by attaching to organic matter and clay minerals that also repel water, they do so. This is beneficial because it may keep the contaminants from flowing to an area where they might be a health threat. Sorption, like dilution and dispersion, appears to reduce the concentration and mass of contamination in the ground water, but does not destroy the contaminants.

Why consider natural attenuation?

In certain situations, natural attenuation is an effective, inexpensive cleanup option and the most appropriate way to remediate some contamination problems. Natural attenuation is sometimes mislabeled as a "no action" approach. However, natural attenuation is really a proactive approach that focuses on the confirmation and monitoring of natural remediation processes rather than relying totally on "engineered" technologies. Mobile and toxic fuel hydrocarbons, for example, are good candidates for natural attenuation. Not only are they difficult to trap because of their mobility, but they are also among the contaminants most easily destroyed by biodegradation. Natural attenuation is non-invasive, and un-

like many elaborate mechanical site cleanup techniques, while natural attenuation is working below ground, the land surface above ground may continue to be used. Natural attenuation can be less costly than other active engineered treatment options, especially those available for ground water, and requires no energy source or special equipment.

Will natural attenuation work at every site?

To estimate how well natural attenuation will work and how long it will take requires a detailed study of the contaminated site. The community and those conducting the cleanup need to know whether natural attenuation, or any proposed remedy, will reduce the contaminant concentrations in the soil and water to legally acceptable levels within a reasonable time.

Natural attenuation may be an acceptable option for sites that have been through some active remediation which has reduced the concentrations of contaminants. However, natural attenuation is not an appropriate option at all sites. The rates of natural processes are typically slow. Long-term monitoring is necessary to demonstrate that contaminant concentrations are continually decreasing at a rate sufficient to ensure that they will not become a health threat. If not, more aggressive remedial alternatives should be considered.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to the treatment of hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means.

Innovative treatment technologies are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

Because the ability of natural attenuation to be an effective cleanup method depends on a variety of conditions, the site needs to be well-characterized to determine if natural attenuation is occurring or will occur. Sites where the soil contains high levels of natural organic matter, such as swampy areas or former marshlands often provide successful conditions for natural attenuation. Certain geological formations such as fractured bedrock aquifers or limestone areas are less likely candidates for natural attenuation because these environments often have a wide variety of soil types that cause unpredictable ground water flow and make predicting the movement of contamination difficult.

Where is natural attenuation being used?

Natural attenuation is being used to clean up petroleum contamination from leaking underground storage tanks across the country.

Within the Superfund program, natural attenuation has been selected as one of the cleanup methods at 73 ground-water-contaminated sites—but is the sole treatment option at only six of these sites. Some of these sites include municipal and industrial land fills, refineries, and recyclers.

At the Allied Signal Brake Systems Superfund site in St. Joseph, Michigan, microorganisms are effectively removing TCE and other chlorinated solvents from ground water. Scientists studied the underground movement of TCE-contaminated ground water from its origin at the Superfund site to where it entered Lake Michigan about half a mile away. At the site itself, they measured TCE concentrations greater than 200,000 micrograms per liter ($\mu\text{g/L}$), but by the time the plume reached the shore of Lake Michigan, the TCE was one thousand times less—only 200 $\mu\text{g/L}$. About 300 feet offshore in Lake Michigan, the concentrations were below EPA's allowable levels. EPA estimated the plume took about 20 years to move from the source of contamination to Lake Michigan—plenty of time for the microorganisms naturally present in the ground water to destroy the TCE without any outside intervention. In fact, microorganisms were destroying about 600 pounds of TCE a year at no cost to taxpayers. EPA determined that nature adequately remediated the TCE plume in St. Joseph.

For More Information

The publications listed below can be ordered free of charge by faxing your request to NCEPI at 513-489-8695. If NCEPI is out of stock of a document, you may be directed to other sources. Some of the documents listed also can be downloaded free of charge from EPA's Cleanup Information (CLU-IN) World Wide Web site (<http://clu-in.com>) or electronic bulletin board (301-589-8366). The CLU-IN help line number is 301-589-8368.

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- *A Citizen's Guide to Bioremediation*, April 1996, EPA 542-F-96-007.
- *Symposium on Intrinsic Bioremediation of Ground Water*, August 1994, EPA 540-R-94-515.
- *Bioremediation Research: Producing Low-Cost Tools to Reclaim Environments*, September 1995, EPA 540-R-95-523a.
- "Natural Bioremediation of TCE," *Ground Water Currents* (newsletter), September 1993, EPA 542-N-93-008.
- "Innovative Measures Distinguish Natural Bioattenuation from Dilution/Sorption," *Ground Water Currents* (newsletter), December 1992, EPA 542-N-92-006.
- *How to Evaluate Alternative Cleanup Technologies for UST Sites*, (Chapter on Natural Attenuation), May 1995, EPA 510-B-95-007.
- *Bioremediation Resource Guide*, September 1993, EPA 542-B-93-004. A bibliography of publications and other sources of information about bioremediation technologies.
- *Engineering Bulletin: In Situ Biodegradation Treatment*, April 1994, EPA 540-S-94-502.
- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Sources*, January 1995, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *WASTECH® Monograph on Bioremediation*, ISBN #1-883767-01-6. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: Atenuación natural

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es la atenuación natural?

La atenuación natural aprovecha procesos naturales para contener la contaminación causada por derrames de productos químicos y reducir la concentración y la cantidad de contaminantes en los lugares afectados. La atenuación natural, conocida también como medidas correctivas intrínsecas, bioatenuación o biocorrección intrínseca, es un método de tratamiento *in situ*, o sea que se dejan los contaminantes donde están mientras se produce la atenuación natural. Con frecuencia se utiliza la atenuación natural como parte de la limpieza de un sitio donde también se recurre al control o la extracción de la fuente de contaminación.

¿Cómo funciona?

Los procesos que contribuyen a la atenuación natural generalmente se encuentran en muchos lugares, pero con diferencias en cuanto a la celeridad y a la eficacia según el tipo de contaminante y las características físicas, químicas y biológicas del suelo y del agua subterránea. Los procesos de atenuación natural a menudo se clasifican en destructivos y no destructivos. Los procesos destructivos destruyen el contaminante. Los procesos no destructivos no destruyen el contaminante, sino que reducen su concentración.

Los procesos de atenuación natural pueden reducir la masa del contaminante (por medio de procesos destructivos tales como biodegradación y transformaciones químicas), reducir su concentración

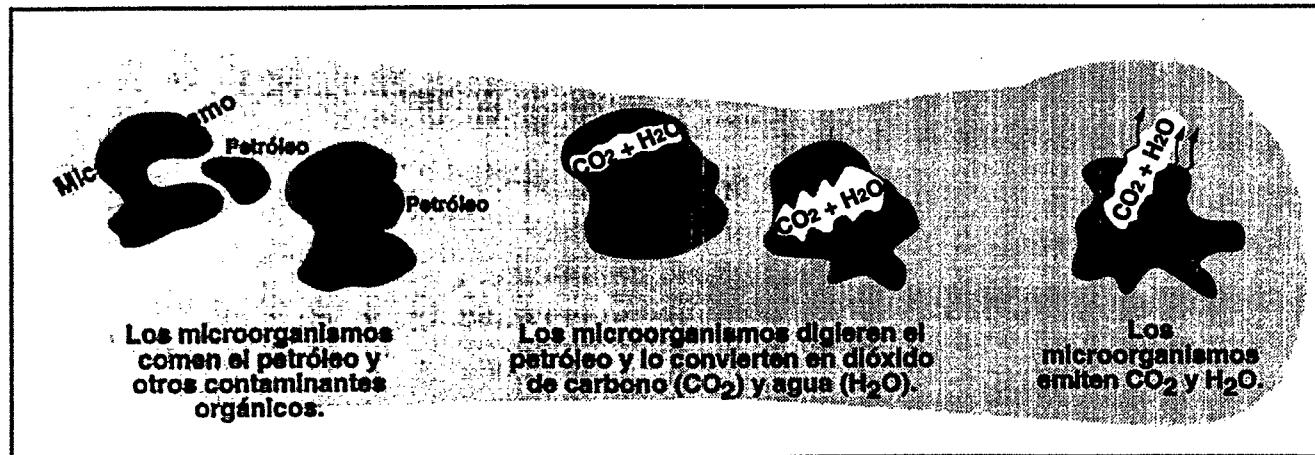
(mediante dilución o dispersión) o unir los contaminantes a partículas de tierra a fin de que la contaminación no se propague o no se extienda demasiado (adsorción).

La biodegradación, llamada también biocorrección, es un proceso en el cual los microorganismos naturales (levaduras, hongos o bacterias) descomponen o degradan sustancias peligrosas, transformándolas en sustancias menos tóxicas o inocuas. Los microorganismos, igual que los seres humanos, comen y digieren sustancias orgánicas, de las cuales se nutren y obtienen energía. (En términos químicos, los compuestos "orgánicos" son aquellos que contienen átomos de carbono y de hidrógeno.) Ciertos microorganismos pueden digerir sustancias orgánicas, como combustibles o solventes, que son peligrosas para los seres humanos. La biodegradación puede producirse en presencia de oxígeno (en condiciones aerobias) o sin él (en condiciones anaerobias). En la mayoría de los entornos subterráneos se produce la biodegradación de contaminantes tanto en forma aerobia como en forma anaerobia. Los microorganismos descomponen los contaminantes orgánicos en productos inocuos, principalmente dióxido de carbono y agua en el caso de la biodegradación aerobia (figura 1). Una vez degradados los contaminantes, la población de microorganismos disminuye porque ha agotado su fuente de alimentos. Los microorganismos muertos o

Perfil de la atenuación natural

- Consiste en el uso de procesos naturales para limpiar sitios contaminados.
- Es una técnica no invasiva que permite usar productivamente el lugar mientras se realiza la limpieza.
- Requiere un estudio pormenorizado de las condiciones del lugar y la vigilancia de la concentración de contaminantes.

Figura 1 Esquema de la biodegradación aerobia en el suelo



una población pequeña de microorganismos sin alimentos no presentan riesgo de contaminación. En la ficha titulada *Guía del ciudadano: Medidas biocorrectivas* se describe el proceso con pormenores (véase la página 4).

Muchos contaminantes orgánicos, como el petróleo, pueden ser biodegradados por microorganismos en el entorno subterráneo. Por ejemplo, con procesos de biodegradación se pueden eliminar eficazmente del suelo y del agua subterránea hidrocarburos tales como gasolina y compuestos de BTEX (benceno, tolueno, etilbenceno y xilenos). La biodegradación también puede descomponer solventes clorados, como tricloroetileno (TCE), en el agua subterránea, pero si no se trata de lugares contaminados por petróleo la acción es más difícil de prever y es eficaz en un porcentaje menor de sitios. Los solventes clorados, que se usan mucho para desengrasar motores de aviones, repuestos de automóviles y componentes electrónicos, se encuentran entre los contaminantes orgánicos más comunes del agua subterránea. Cuando los compuestos clorados se biodegradan, es importante que la degradación sea completa porque algunos productos de la descomposición pueden ser más tóxicos que los compuestos originales.

Los efectos de dilución y dispersión parecen reducir la concentración del contaminante pero no lo destruyen. Se puede filtrar agua relativamente limpia de la superficie del suelo y mezclarla con agua subterránea contaminada, diluyéndola. Puede fluir agua subterránea limpia de un lugar subterráneo a zonas contaminadas; la dispersión de contaminantes que van alejándose del trayecto principal de la estela

contaminada también lleva a una disminución de la concentración del contaminante en una zona determinada.

La adsorción se produce cuando los contaminantes se adhieren a partículas subterráneas, es decir, son sorbidos. Los hidrocarburos tienden a repeler el agua, igual que la mayoría de las sustancias oleosas. Aprovechan cualquier oportunidad para escaparse del agua subterránea adhiriéndose a materia orgánica y minerales arcillosos que también repelen el agua. Eso es beneficioso porque puede impedir que los contaminantes fluyan a un lugar donde presenten un riesgo para la salud. La sorción, igual que la dilución y la dispersión, parece reducir la concentración y la masa de contaminantes en el agua subterránea, pero no los destruye.

¿En qué casos convendría usar la atenuación natural?

En ciertas situaciones, la atenuación natural es una opción eficaz y económica para realizar una limpieza y la forma más apropiada de corregir algunos problemas de contaminación. A veces se dice erróneamente que la atenuación natural es el método de la "inacción." Sin embargo, la atenuación natural es realmente un método activo centrado en la confirmación y la vigilancia de procesos de corrección natural, en vez de depender totalmente de técnicas "dirigidas." Los hidrocarburos móviles y tóxicos, por ejemplo, son buenos candidatos para la atenuación natural. No sólo son difíciles de atrapar debido a su movilidad, sino que también se encuentran entre los contaminantes que más fácilmente se destruyen con la biodegradación. La atenuación natural es un método no invasivo; a diferencia de

muchas técnicas complejas de limpieza mecánica, la superficie del suelo puede seguir usándose mientras se produce la atenuación natural en el subsuelo. La atenuación natural puede ser menos costosa que otras opciones dirigidas para el tratamiento, especialmente las que se usan para el agua subterránea, y no requiere una fuente de energía ni equipo especial.

¿Dará resultado esta técnica en cualquier lugar?

Para calcular el resultado que dará la atenuación natural y cuánto tardará se necesita un estudio pormenorizado del lugar contaminado. Los pobladores locales y las personas que realicen la limpieza deben saber si la atenuación natural o cualquier otra medida correctiva propuesta reducirá la concentración de contaminantes en el suelo y en el agua a niveles legalmente aceptables en un plazo prudencial.

La atenuación natural podría ser una opción aceptable para lugares donde se haya reducido la concentración de contaminantes como resultado de la aplicación de algunas medidas correctivas. Sin embargo, la atenuación natural no es una opción apropiada para cualquier lugar. Los procesos naturales generalmente son lentos. Se necesita una vigilancia a largo plazo para comprobar que la concentración de contaminantes disminuya continuamente y lo suficiente para que no se convierta en una amenaza para la salud. De no ser así, se debería considerar la posibilidad de aplicar medidas correctivas más energéticas.

¿Qué son las técnicas de tratamiento innovadoras?

Las técnicas de tratamiento son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos.

Las técnicas de tratamiento innovadoras son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Como la eficacia de la atenuación natural como método de limpieza depende de diversas condiciones, es necesario caracterizar bien el sitio a fin de determinar si se está produciendo o se producirá atenuación natural. Los suelos con gran cantidad de materia orgánica, como las zonas pantanosas o antiguos pantanos, con frecuencia son aptos para la atenuación natural. Ciertas formaciones geológicas, como acuíferos de lecho rocoso fracturado o zonas calizas, son menos apropiadas para la atenuación natural porque en estos entornos a menudo hay suelos muy diversos que ocasionan un flujo imprevisible del agua subterránea y dificultan la previsión del movimiento de los contaminantes.

¿Dónde se está usando esta técnica?

La atenuación natural se está usando para limpiar la contaminación causada por fugas de petróleo de depósitos subterráneos en todo el país.

En el marco del programa del Superfund se ha seleccionado la atenuación natural como uno de los métodos de limpieza de 73 lugares con agua subterránea contaminada, pero es la única opción para el tratamiento en sólo seis de ellos. Algunos de estos sitios son vertederos municipales e industriales, refinerías y centros de reciclaje. En el predio de Allied Signal Brake Systems, en St. Joseph (Michigan), que está comprendido en el Superfund, los microorganismos están extrayendo eficazmente TCE y otros solventes clorados del agua subterránea. Los científicos estudiaron el movimiento subterráneo del agua contaminada por TCE desde su lugar de origen en el sitio comprendido en el Superfund hasta el punto de entrada al lago Michigan, a unos 800 metros de distancia. En el predio se encontraron concentraciones de TCE superiores a 200.000 microgramos por litro ($\mu\text{g/l}$), pero cuando la estela llegó a la orilla del lago Michigan, contenía mil veces menos TCE (solamente 200 $\mu\text{g/l}$). En el lago, a unos 90 metros de la orilla, las concentraciones eran inferiores a las permitidas por el EPA. Según los cálculos del EPA, la estela tardó alrededor de 20 años en llegar desde la fuente de contaminación hasta el lago Michigan, dando suficiente tiempo a los microorganismos naturales que están en el agua subterránea para destruir el TCE sin intervención externa. De hecho, los microorganismos estaban destruyendo alrededor de 270 kg de TCE por año sin costo alguno para los contribuyentes. El EPA determinó que la naturaleza había corregido de forma adecuada la estela de TCE en St. Joseph.

Para más información

Las publicaciones que se indican a continuación pueden obtenerse gratis del NCEPI. Para encargarlas, envíe su pedido por fax al 513-489-8695. Si alguno de estos documentos se ha agotado, puede dirigirse a otras fuentes. Algunos de los documentos de la lista pueden recibirse gratis por computadora desde el sitio del EPA en la World Wide Web con información sobre operaciones de limpieza (CLU-IN), <http://clu-in.com>, de la cartelera electrónica, 301-589-8366. El número para pedir asistencia en relación con CLU-IN es 301-589-8368.

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- *Guía del ciudadano: Medidas biocorrectivas, abril de 1996, EPA 542-F-96-023.*
- *Symposium on Intrinsic Bioremediation of Ground Water, agosto de 1994, EPA 540-R-94-515.*
- *Bioremediation Research: Producing Low-Cost Tools to Reclaim Environments, septiembre de 1995, EPA 540-R-95-523a.*
- *"Natural Bioremediation of TCE," Ground Water Currents (boletín), septiembre de 1993, EPA 542-N-93-00*
- *"Innovative Measures Distinguish Natural Bioattenuation from Dilution/Sorption," Ground Water Currents (boletín), diciembre de 1992, EPA 542-N-92-006.*
- *How to Evaluate Alternative Cleanup Technologies for UST Sites* (capítulo sobre atenuación natural), mayo de 1995, EPA 510-B-95-007.
- *Bioremediation Resource Guide*, septiembre de 1993, EPA 542-B-93-004. **Bibliografía de publicaciones y otras fuentes de información sobre técnicas biocorrectivas.**
- *Engineering Bulletin: In Situ Biodegradation Treatment*, abril de 1994, EPA 540-S-94-502.
- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, enero de 1995, EPA 542-B-95-001. **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- *WASTECH® Monograph on Bioremediation*, ISBN #1-883767-01-6. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Phytoremediation

Technology Innovation Office

Technology Fact Sheet

What is phytoremediation?

Phytoremediation is the use of plants and trees to clean up contaminated soil and water. Growing and, in some cases, harvesting plants on a contaminated site as a remediation method is an aesthetically pleasing, solar-energy driven, passive technique that can be used along with, or in some cases, in place of mechanical cleanup methods.

Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, and landfill leachates.

How does phytoremediation work?

Phytoremediation (the term *phyto-* means *plant*) is a general term for several ways in which plants are used to clean up, or *remediate*, sites by removing pollutants from soil and water. Plants can break down, or *degrade*, organic pollutants or stabilize metal contaminants by acting as filters or traps. Some of the methods that are being tested are described in this fact sheet.

Metals Remediation

At sites contaminated with metals, plants are used to either stabilize or remove the metals from the soil and ground water through two mechanisms: *phytoextraction* and *rhizofiltration*.

Phytoextraction, also called phytoaccumulation, refers to the uptake of metal contaminants by plant

roots into plant stems and leaves (Figure 1). Certain plants absorb unusually large amounts of metals in comparison to other plants. One or a combination of these plants is selected and planted at a particular site based on the type of metals present and other site conditions. After the plants have been allowed to grow for some time, they are harvested and either incinerated or composted to recycle the metals. This procedure can be repeated as many times as necessary to bring contaminant levels in the soil down to allowable limits. If plants are incinerated, their ash must be disposed of in a hazardous waste landfill, but the volume of ash will only be about 10% of the volume that would be created if the contaminated soil itself were dug up for treatment.

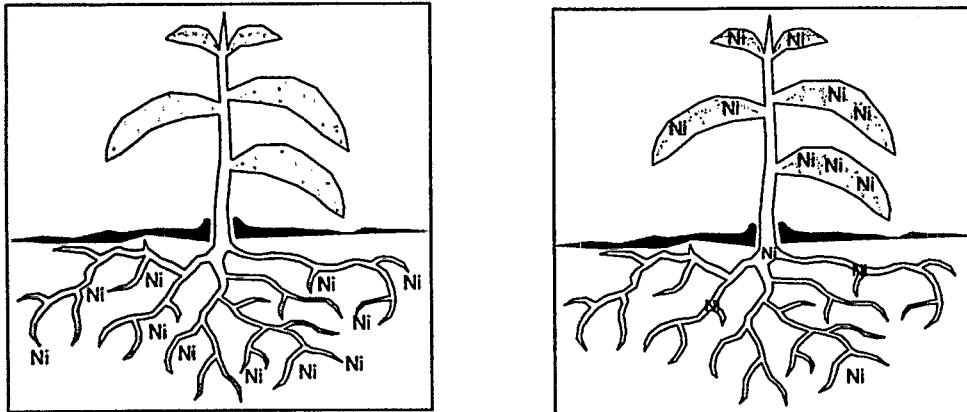
Metals such as nickel, zinc, and copper are the best candidates for removal by phytoextraction because they happen to be the favorites of the approximately 400 known plants that absorb unusually large amounts of metals. Plants that absorb lead and chromium are being studied and tested.

Rhizofiltration (*rhizo-* means *root*) has shown promise for dealing with metals contamination in water. Rhizofiltration is similar to phytoextraction, but the plants to be used for cleanup are raised in greenhouses with their roots in water rather than in soil. When the plants have developed a large root system, contaminated water is collected from a waste site and

A Quick Look at Phytoremediation

- Is an aesthetically-pleasing, passive, solar-energy driven cleanup technique.
- Is most useful at sites with shallow, low levels of contamination.
- Is useful for treating a wide variety of environmental contaminants.

Figure 1. Uptake of Metals (Nickel) by Phytoextraction



Nickel is removed from soil by moving up into plant roots, stems, and leaves. The plant is then harvested and disposed of and the site replanted until the nickel in the soil is lowered to acceptable levels.

brought to the plants where it is substituted for their water source. The roots take up the water and the contaminants along with it. As the roots become saturated with contaminants, they are harvested and disposed of. In addition to being useful for removing metals from water, rhizofiltration may prove useful for industrial discharge, agricultural runoff, acid mine drainage, and radioactive contamination. For example, sunflowers were used successfully to remove radioactive contaminants from pond water in a test at Chernobyl, Ukraine.

Treating Organic Contaminants

Organic contaminants (those that contain carbon and hydrogen atoms) are common environmental pollutants. There are several ways plants can be used for the phytoremediation of these contaminants: *phytodegradation*, *enhanced rhizosphere biodegradation*, *organic pumps*, and *phytovolatilization*.

Phytodegradation is a process in which plants are able to *degrade* (break down) organic pollutants. In some cases, the pollutants degraded into simpler molecules are used to help the plant grow faster (Figure 2). Plants contain *enzymes*, a broad category of chemical substances that cause rapid chemical reactions to occur. Some enzymes break down and convert ammunition wastes, others degrade chlorinated solvents such as trichloroethylene (TCE), and others degrade herbicides.

Enhanced rhizosphere biodegradation takes place in the soil surrounding the plant roots (the *rhizosphere*) and is a much slower process than phytodegradation. Microorganisms (yeast, fungi, or bacteria) consume and digest organic substances for nutrition and energy. Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans and break them down into harmless products in a process called *biodegradation*. Natural substances released by the plant roots—sugars, alcohols, and acids—contain organic carbon that provides food for soil microorganisms and the additional nutrients *enhance* their activity. Biodegradation is also aided by the way plants loosen the soil and transport water to the area. The fact sheet entitled *A Citizen's Guide to Bioremediation* describes the biodegradation process in detail (see page 4).

Trees can act as **organic pumps** when their roots reach down toward the water table and establish a dense root mass that takes up large quantities of water. Poplar trees, for example, pull out of the ground 30 gallons of water per day, and cottonwoods can absorb up to 350 gallons per day. The pulling action

What Is An Innovative Treatment Technology?

- **Treatment technologies** are processes applied to the treatment of hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means.
- **Innovative treatment technologies** are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

caused by the roots decreases the tendency of surface pollutants to move downward towards ground water and into drinking water. Poplars planted along stream beds in agricultural areas reduce the amount of excess fertilizer and herbicides that get into the streams and ground water. In another similar application, trees planted on top of landfills as organic substitutes for the traditional clay or plastic caps, suck up rainwater that could otherwise seep through the landfill and come out the bottom as contaminated "leachate."

Phytovolatilization occurs as growing trees and other plants take up water and the organic contaminants in it. Some of these contaminants can pass through the plants to the leaves and evaporate, or *volatilize*, into the atmosphere. Poplar trees, for example, volatilize 90% of the TCE they suck up.

Does phytoremediation work at every site?

Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, and landfill leachates. Phytoremediation is used in combination with other cleanup approaches as a "finishing" step. Although phytoremediation is significantly slower than mechanical methods, and is limited to the depth that the roots can reach, it can clean out the last remains of contaminants trapped in the soil that mechanical treatment techniques sometimes leave behind.

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and ground

water. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground. Contaminated ground water very deep underground may be treated by pumping the water out of the ground and using it to irrigate plantations of trees.

Further research is needed to study the effects on the food chain that could occur if insects and small rodents eat the plants that are collecting metals and are then eaten by larger mammals. Also, scientists still need to establish whether contaminants can collect in the leaves and wood of trees used for phytoremediation and be released when the leaves fall in the autumn or when firewood or mulch from the trees is used.

Where has it been used?

Phytoremediation has been successfully tested in many locations. In Iowa, poplar trees planted along a stream bank between a corn field and the stream acted as natural pumps to keep toxic herbicides, pesticides, and fertilizers out of the streams and ground water. When the trees were three years old, researchers tested the levels of the nitrate contamination in the ground water at the edge of the cornfield and found it to be 150 milligrams per liter (mg/L). The ground water among the poplar trees along the stream bank, however, had nitrate concentration of only 3 mg/L—well under the EPA nitrate limit of 45 mg/L in drinking water. The table on page 4 lists some phytoremediation projects.

Figure 2. Destruction of Organic Contaminants by Phytodegradation

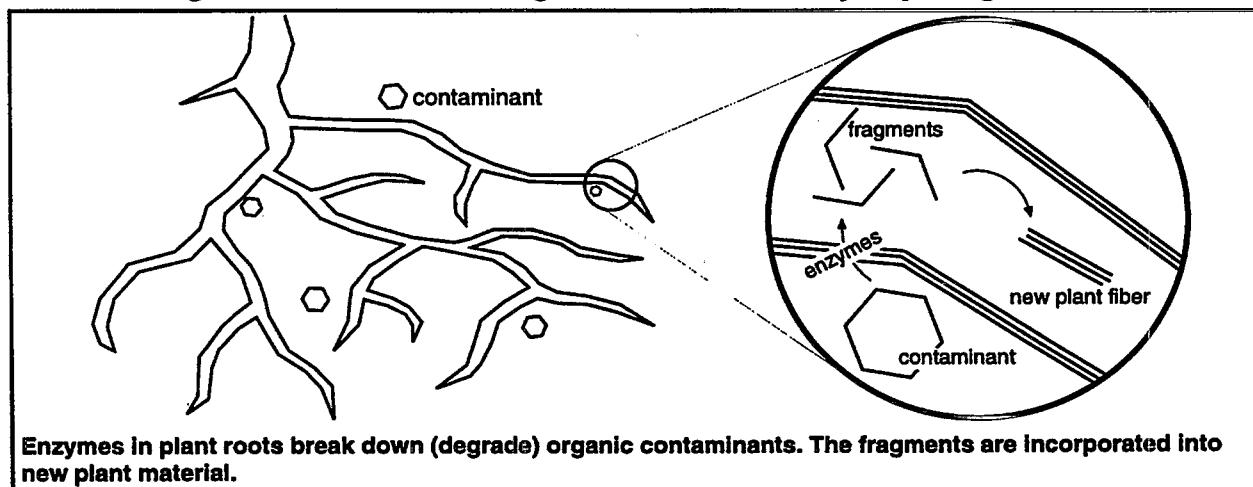


Table 1. Examples of Sites Testing Phytoremediation*

Location	Application	Contaminants	Medium	Plant
Ogden, UT	Phytoextraction	Petroleum hydrocarbons	Soil Ground water	Alfalfa, Poplar Juniper, Fescue
Portsmouth, VA	Rhizofiltration Phytodegradation	Petroleum	Soil	Grasses Clover
Milan, TN	Phytodegradation	Explosives wastes	Sediment	Duckweed Parrot feather
Aberdeen, MD	Organic Pumps Phytovolatilization Rhizofiltration	Trichloroethylene Trichloroethane	Ground Water	Poplar trees

*Not all waste types and site conditions are comparable. Each site must be individually investigated and tested.
Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

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- "Tree Buffers Protect Shallow Ground Water at Contaminated Sites," *Ground Water Currents* (newsletter), December 1993, EPA 542-N-93-011.
- Recent Developments for *In Situ* Treatment of Metal Contaminated Soils, (Available Fall 1996), EPA 542-R-96-008.
- *A Citizen's Guide to Bioremediation*, April 1996, EPA 542-F-96-007.
- *Soil Stabilization Action Team*, April 1996, EPA 542-F-96-010d.
- "Mother Nature's Pump and Treat," by Kalle Matso in *Civil Engineering*, October 1995, pages 46-49.
- "The Green Clean," by Kathryn Brown Sargeant in *BioScience*, October 1995, pages 579-582.

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Guía del ciudadano: Medidas fitocorrectivas

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué son las medidas fitocorrectivas?

Las medidas fitocorrectivas consisten en el uso de plantas y árboles para limpiar agua y suelo contaminados. Cultivar plantas en un lugar contaminado, y en algunos casos cosecharlas, como método correctivo es una técnica pasiva estéticamente agradable que aprovecha la energía solar y se puede usar junto con métodos de limpieza mecánicos o en algunos casos en vez de métodos de este tipo.

Las medidas fitocorrectivas pueden usarse para limpiar metales, plaguicidas, solventes, explosivos, petróleo crudo, hidrocarburos poliaromáticos y lixiviados de vertederos.

¿Cómo funcionan?

Fitocorrección (el prefijo *fito-* significa *planta*) es un término general que se refiere a varios usos de plantas para limpiar o *corregir* sitios extrayendo contaminantes del suelo y el agua. Las plantas actúan como filtros o trampas y pueden descomponer o *degradar* contaminantes orgánicos o estabilizar contaminantes metálicos. En esta ficha tecnológica se describen algunos de los métodos que se están probando.

Medidas correctivas para metales

En lugares contaminados con metales, se usan plantas para estabilizar o retirar los metales del suelo y del agua subterránea por medio de dos mecanismos: *fitoextracción* y *rizofiltración*.

La *fitoextracción*, conocida también como *fitoacumulación*, es la captación de metales contaminantes

por las raíces de las plantas y su acumulación en tallos y hojas (figura 1). Algunas plantas absorben cantidades extraordinarias de metales en comparación con otras. Se selecciona una de estas plantas o varias de este tipo y se plantan en un sitio según los metales presentes y las características del lugar. Después de un tiempo, cuando las plantas han crecido, se cortan y se incineran o se deja que se transformen en abono vegetal para reciclar los metales. Este procedimiento se puede repetir la cantidad de veces que sea necesario para reducir la concentración de contaminantes en el suelo a límites aceptables. Si se incineran las plantas, las cenizas deben colocarse en un vertedero para desechos peligrosos, pero la cantidad de ceniza será sólo alrededor del 10% del volumen de los desechos que habría que eliminar si se excavara el suelo contaminado para tratarlo.

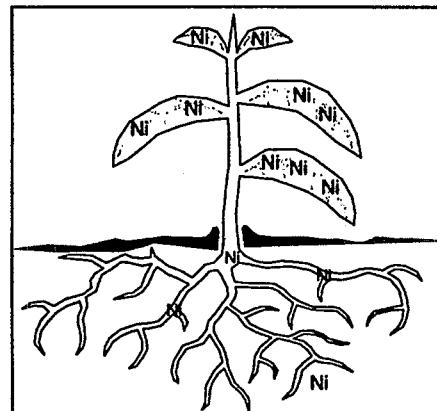
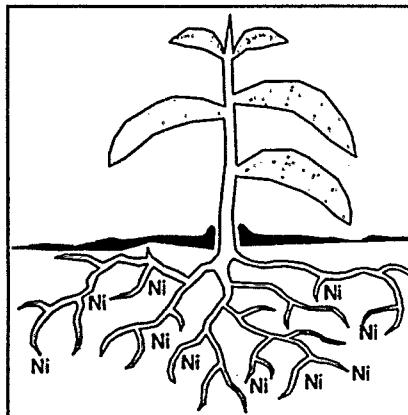
Los mejores candidatos para la *fitoextracción* son el níquel, el cinc y el cobre porque son los preferidos de las 400 plantas, aproximadamente, que se sabe que absorben cantidades extraordinarias de metales. Se están estudiando y probando plantas que absorben plomo y cromo.

La *rizofiltración* (rizo- significa rafz) es una técnica prometedora para abordar el problema de la contaminación del agua con metales. La *rizofiltración* es similar a la *fitoextracción*, pero las plantas que se usan para la limpieza se cultivan en invernaderos con las raíces en agua, en vez de tierra. Cuando las plantas tienen un sistema de raíces bien desarrollado, se recoge agua contaminada de un vertedero, se transporta hasta el lugar donde están las plantas

Perfil de las medidas fitocorrectivas

- Son una técnica de limpieza pasiva, estéticamente agradable, que aprovecha la energía solar.
- Son más útiles en lugares donde la contaminación es poco profunda y no es muy grande.
- Son útiles para tratar una gran variedad de contaminantes del medio ambiente.

Figura 1. Captación de metales (níquel) por fitoextracción



El níquel del suelo sube por las raíces de las plantas hasta los tallos y las hojas. Después se cortan las plantas y se eliminan, y se vuelve a plantar el lugar hasta que la concentración de níquel en el suelo baje a niveles aceptables.

y se colocan las plantas en esta agua. Las raíces absorben el agua junto con los contaminantes. A medida que las raíces se saturan de contaminantes, se cortan y se eliminan. Además de extraer metales del agua, la rizofiltración puede ser útil para descargas industriales, escorrentía de tierras agrícolas, drenaje de minas de ácidos y contaminantes radiactivos. Por ejemplo, las semillas de girasol dieron resultado para retirar contaminantes radiactivos del agua de una laguna en una prueba realizada en Chernobyl (Ucrania).

Tratamiento de contaminantes orgánicos

Los contaminantes orgánicos (es decir, los que contienen átomos de carbono e hidrógeno) son comunes en el medio ambiente. Hay varias formas en que se pueden usar plantas para la fitocorrección de estos contaminantes: *fitodegradación, biodegradación mejorada de la rizosfera, bombeo orgánico y fitovolatilización*.

La fitodegradación es un proceso mediante el cual las plantas *degradan* (descomponen) contaminantes orgánicos. En algunos casos, los contaminantes

degradados en moléculas más simples se usan para acelerar el crecimiento de las plantas (figura 2). Las plantas tienen *enzimas*, categoría amplia de sustancias químicas que causan reacciones químicas rápidas. Algunas enzimas se descomponen y convierten desechos de municiones, otras degradan solventes clorados tales como tricloroetileno (TCE) y otras degradan herbicidas.

La biodegradación intensificada de la rizosfera se produce en la tierra que rodea las raíces de las plantas (*la rizosfera*). Es un proceso mucho más lento que la fitodegradación. Los microorganismos (levaduras, hongos o bacterias) consumen y digieren sustancias orgánicas, de las cuales se alimentan y obtienen energía. Algunos microorganismos pueden digerir sustancias orgánicas tales como combustibles o solventes, que son peligrosas para los seres humanos, y descomponerlas en productos inocuos mediante un proceso llamado *biodegradación*. Las sustancias naturales liberadas por las raíces de las plantas (azúcar, alcohol y ácidos) contienen carbono orgánico, del cual se alimentan los microorganismos del suelo, y los nutrientes adicionales *intensifican* su actividad. Además, las plantas aflojan la tierra y transportan agua al lugar, facilitando así la biodegradación. En la ficha tecnológica titulada *Guía del ciudadano: Medidas biocorrectivas* se describe el proceso de biodegradación en forma pormenorizada (véase la página 4).

Los árboles pueden realizar una acción de *bombeo orgánico* cuando sus raíces bajan hacia la capa freática, formando una masa densa de raíces que absorbe una gran cantidad de agua. Los álamos, por ejemplo, absorben 113 litros de agua por día, y hay una variedad de álamo (*Populus deltoides*) que absorbe hasta 1.325 litros por día.

¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Las *técnicas de tratamiento innovadoras* son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

La acción de bombeo de las raíces disminuye la tendencia de los contaminantes superficiales a descender hacia el agua subterránea y el agua potable. En zonas agrícolas, los álamos plantados a lo largo de cursos de agua reducen el excedente de fertilizantes y herbicidas que va a parar a los cursos de agua y al agua subterránea. Asimismo, los árboles plantados en vertederos como sustitutos orgánicos de la tradicional capa de arcilla o de plástico absorben agua de lluvia que, de lo contrario, se filtraría por el vertedero y llegaría al fondo en forma de "lixiviado" contaminado.

La fitovolatilización se produce a medida que los árboles y otras plantas en crecimiento absorben agua junto con contaminantes orgánicos. Algunos de los contaminantes pueden llegar hasta las hojas y evaporarse o *volatilizarse* en la atmósfera. Los álamos, por ejemplo, volatilizan el 90% del TCE que absorben.

¿Dará resultado esta técnica en cualquier lugar?

Las medidas fitocorrectivas pueden usarse para limpiar metales, plaguicidas, solventes, explosivos, petróleo crudo, hidrocarburos poliaromáticos y lixiviados de vertederos. La fitocorrección se combina con otros métodos de limpieza en la etapa de "acabado." Aunque las medidas fitocorrectivas son mucho más lentas que los métodos mecánicos y llegan solamente a la profundidad hasta la cual llegan las raíces, pueden eliminar los últimos restos de contaminantes atrapados en el suelo que a veces quedan con las técnicas mecánicas de tratamiento.

Generalmente, las medidas fitocorrectivas se usan en lugares con baja concentración de contaminantes y en

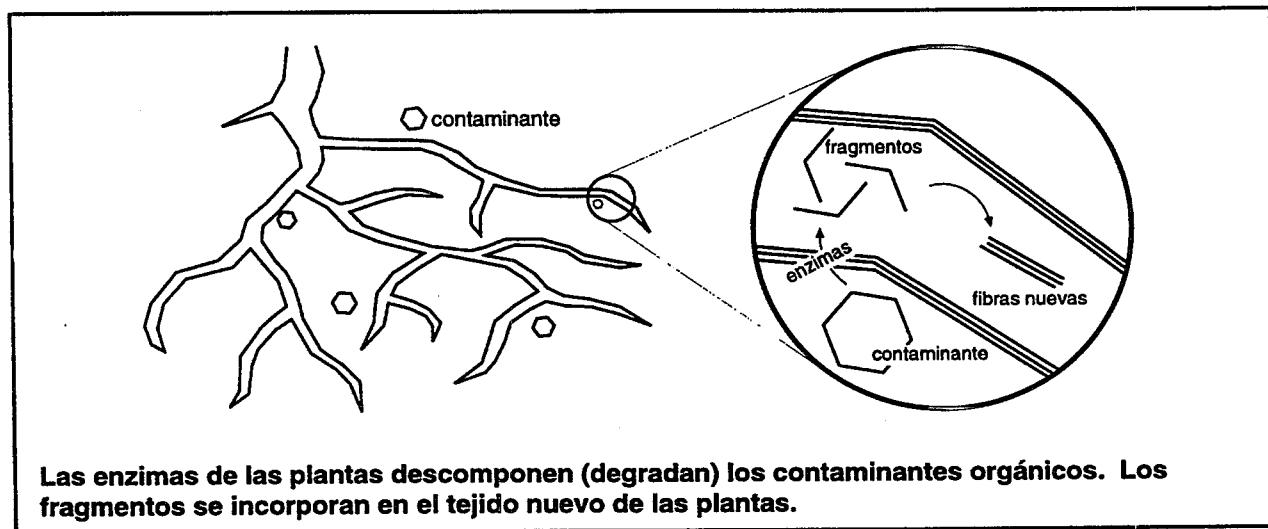
suelos, cursos de agua y agua subterránea poco profundos. Sin embargo, los investigadores han observado que con árboles (en vez de plantas más pequeñas) se puede tratar la contaminación a mayor profundidad porque las raíces de los árboles penetran a mayor profundidad en el suelo. El agua subterránea contaminada a gran profundidad se puede extraer por bombeo y usar para regar arboledas.

Se necesitan más investigaciones para estudiar los efectos en la cadena alimentaria que se producirían si algunos insectos y roedores pequeños comieran las plantas con metales acumulados y fuesen a su vez comidos por mamíferos de mayor tamaño. Además, los científicos todavía no saben si se pueden acumular contaminantes en las hojas y la madera de árboles usados con fines de fitocorrección y ser liberados después cuando se caen las hojas en el otoño o cuando se usa leña o corteza desmenuzada de los árboles.

¿Dónde se ha usado esta técnica?

Las medidas fitocorrectivas han dado buenos resultados en varios lugares. En Iowa se plantaron álamos entre un curso de agua y un maízal, que realizaron una acción de bombeo natural para impedir que llegaran herbicidas tóxicos, plaguicidas y fertilizantes al curso de agua y al agua subterránea. Cuando los árboles cumplieron tres años, se hizo un análisis del agua subterránea al borde del maízal para determinar el grado de contaminación por nitratos y se observó que contenía 150 miligramos por litro (mg/l), pero el agua subterránea entre los álamos a lo largo del curso de agua contenía solamente 3 mg de nitratos por litro, mucho menos que el límite establecido por el EPA de 45 mg/l para el agua potable. En el cuadro de la página 4 se enumeran algunos proyectos de fitocorrección.

Figura 2. Destrucción de contaminantes orgánicos por fitodegradación



Las enzimas de las plantas descomponen (degradan) los contaminantes orgánicos. Los fragmentos se incorporan en el tejido nuevo de las plantas.

Cuadro 1
Ejemplos de sitios donde se están probando técnicas fitocorrectivas*

Lugar	Tratamiento	Contaminantes	Medio	Planta
Ogden (Utah)	Fitoextracción	Hidrocarburos (petróleo)	Suelo Agua subterránea	Alfalfa, álamos Enebro, festuca
Portsmouth (Virginia)	Rizofiltración Fitodegradación	Petróleo	Suelo	Pastos Trébol
Milan (Tennessee)	Fitodegradación	Desechos de explosivos	Sedimentos	Lenteja de agua Pluma de papagayo
Aberdeen (Maryland)	Bombeo orgánico Fitovolatilización Rizofiltración	Tricloroetileno Tricloroetano	Agua	Álamos subterránea

* No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

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- "Tree Buffers Protect Shallow Ground Water at Contaminated Sites," *Ground Water Currents* (boletín), diciembre de 1993, EPA 542-N-93-011.
- *Recent Developments for In Situ Treatment of Metal Contaminated Soils* (se publicará el cuarto trimestre de 1996), EPA 542-R-96-008.
- *Guía del ciudadano: Medidas biocorrectivas*, abril de 1996, EPA 542-F-96-007.
- *Soil Stabilization Action Team*, abril de 1996, EPA 542-F-96-010d.
- "Mother Nature's Pump and Treat," de Kalle Matso, en *Civil Engineering*, octubre de 1995, páginas 46-49.
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A Citizen's Guide to Soil Vapor Extraction and Air Sparging

Technology Innovation Office

Technology Fact Sheet

What is soil vapor extraction?

Soil vapor extraction, known as SVE, is the most frequently selected innovative treatment at Superfund sites. It is a relatively simple process that physically separates contaminants from soil. As the name suggests, SVE *extracts* contaminants from the *soil in vapor form*. Therefore, SVE systems are designed to remove contaminants that have a tendency to *volatilize* or evaporate easily. SVE removes *volatile* organic compounds (VOCs) and some *semi-volatile* organic compounds (SVOCs) from soil beneath the ground surface in the unsaturated zone—that part of the subsurface located above the water table. By applying a vacuum through a system of underground wells, contaminants are pulled to the surface as vapor or gas. Often, in addition to vacuum extraction wells, air *injection* wells are installed to increase the air flow and improve the removal rate of the contaminant. An added benefit of introducing air into the soil is that it can stimulate *bioremediation* of some contaminants.

SVE is sometimes called *in situ volatilization*, *enhanced volatilization*, *in situ soil venting*, *forced soil venting*, *in situ air stripping*, or *soil vacuum extraction*.

What is air sparging?

Used alone, soil vapor extraction cannot remove contaminants in the *saturated zone* of the subsurface, the water-soaked soil that lies below the water table. At sites where contamination is in the saturated zone, a process called air sparging may be used along with the SVE system. Air sparging means pumping air into the saturated zone to help flush (bubble) the contaminants up into the unsaturated zone where the SVE extraction wells can remove them (Figure 1).

For air sparging to be successful, the soil in the saturated zone must be loose enough to allow the injected air to readily escape up into the unsaturated zone. Air sparging, therefore, will work fastest at sites with coarse-grained soil, like sand and gravel.

A Quick Look at Soil Vapor Extraction

- Pulls contaminants from soil in vapor form.
- Provides an oxygen source which may stimulate bioremediation of some contaminants.
- Most frequently used innovative treatment technology.

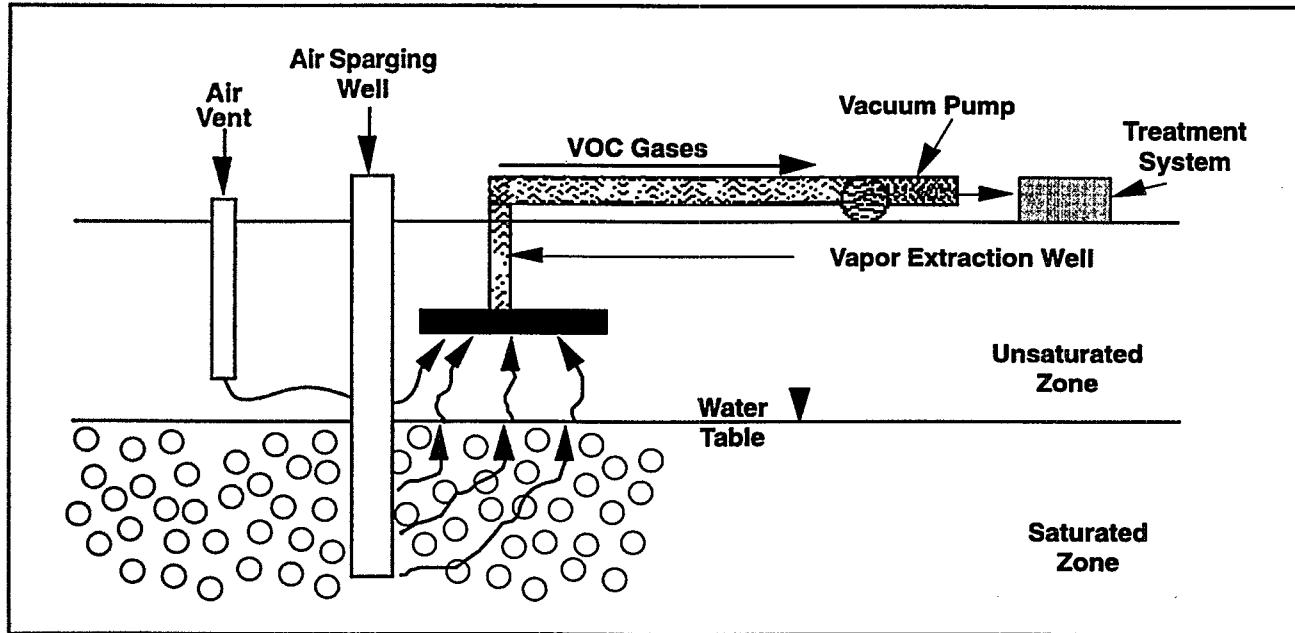
A Quick Look at Air Sparging

- Extends the effectiveness of soil vapor extraction to include contaminants that exist in ground water.
- Can accelerate cleanup at pump-and-treat sites.
- Provides an oxygen source which may stimulate bioremediation of some contaminants.



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Figure 1
A Combined Soil Vapor Extraction/Air Sparging System



As with SVE, an added benefit of air sparging is that it provides an oxygen source that helps stimulate the *bioremediation* of some contaminants. Bioremediation is an innovative treatment technology that uses microorganisms, such as bacteria, that live in the soil or groundwater to break down contaminants into harmless substances. (Bioremediation is explained in detail in another Citizen's Guide. See the "For More Information" box on page 4.) Air sparging also can be a quick and effective treatment for VOCs in groundwater.

How does an SVE system work?

The first step to constructing an SVE system is to install vapor extraction wells and injection wells (or air vents) in the contaminated area. Air injection wells use air compressors to force air into the ground. Air vents serve the same function as air injection wells, but are passive—instead of pumping air they just provide a passage for air to be drawn into the ground. When incoming air passes through the soil on its way to the extraction wells, contaminants evaporate out of the spaces between the soil particles and are pulled by the air to the wells and removed.

Vapor extraction wells can be placed either vertically or horizontally. Typically, they are placed

vertically and are designed to penetrate the lower portion of the unsaturated zone.

Vapors extracted by the SVE process are typically treated using carbon adsorption, incineration, catalytic oxidation, or condensation. Other methods, such as biological treatment and ultraviolet oxidation, also have been used with SVE systems. The type of treatment chosen depends on which contaminants are present and their concentrations.

Carbon adsorption is the most commonly used treatment for contaminated vapors and is adaptable to a wide range of volatile organic compounds.

When properly designed and operated, SVE is a safe, low maintenance process. Explosion-proof equipment is available to handle the potentially explosive mixtures of extracted gas that may be encountered on some landfill or gasoline spill sites.

SVE with thermal enhancement. SVE performance can be *enhanced* or improved by injecting heated air or steam into the contaminated soil through the injection wells. The heated air or steam helps to "loosen" some less volatile compounds from the soil. Researchers have done large-scale demonstrations of SVE with steam injection at several sites. In

addition to heated air or steam, another enhancement of SVE is the use of radio-frequency (RF) heating to better vaporize or volatilize compounds in clay and silt-type soils. Demonstrations of RF heating are underway.

Dual phase extraction. Dual phase extraction is a treatment system similar to SVE, but the extraction wells are sunk more deeply into the ground—below the water table into the saturated zone. Strong vacuum is applied through the extraction wells to simultaneously remove groundwater and vapors from the subsurface. Once above ground, the extracted vapors and groundwater are separated and treated. Dual phase extraction is more effective than SVE at sites with dense, clayey soil. When dual-phase extraction is combined with bioremediation, air sparging or bioventing, it can shorten cleanup times.

Why consider SVE or air sparging?

SVE is very effective at removing VOCs from the unsaturated zone. With the addition of an air sparging system, contaminants can be removed from the saturated zone as well. Neither technique requires excavation of the contaminated soil. (Excavation is undesirable because it is expensive, creates dust, and allows volatile contaminants to escape untreated into the atmosphere.) The extracted vapors usually require treatment, but costs for treating extracted vapors and liquids are low compared to the costs of technologies requiring excavation. The technologies are relatively simple to install, can be used effectively in combination with other treatment technologies, and are effective under a variety of site conditions.

Will SVE or air sparging work at every site?

SVE and air sparging may be good choices at sites contaminated with solvents and other volatile organic compounds (such as trichloroethane, trichloroethylene, benzene, toluene, ethylbenzene, and xylene) and fuels. Because properties of the soil have such an important effect on the movement of soil vapors, the performance and design of SVE and air sparging systems depend greatly on the properties of the soil. SVE is best used at sites with loose unsaturated soil, such as sand, gravel, and coarse silt or fractured bedrock. However, it has been applied to sites with denser soils, although treatment may take longer.

Also, the higher the moisture content of the soil, the slower SVE works.

Where are SVE and air sparging being used?

SVE has been used at many Superfund and other hazardous waste sites. The Verona Well Field in Michigan is a Superfund site at which SVE was used to treat a one-half acre area to a depth of 20 feet contaminated with trichloroethene, tetrachloroethylene, and "BTEX," a mixture of benzene, toluene, ethylbenzene, and xylene. The SVE system removed and treated a total of 45,000 pounds of contaminants from the treatment area. EPA set target cleanup levels for 19 different contaminants at the site and the SVE system successfully met the goals for all the contaminants. Table 1 on page 4 lists other Superfund sites at which SVE, air sparging, and dual-phase extraction are planned or have been used.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste. *Innovative treatment technologies* are technologies that have been tested, selected or used for treatment of hazardous waste or contaminated materials but still lack well-documented cost and performance data under a variety of operating conditions.

Some innovative treatment technologies, such as SVE and thermal desorption, are so widely used that the term "innovative" may seem inappropriate. However, innovative variations on these technologies are still being developed and EPA still is not able to predict with certainty the time and cost required to clean up a site using them. For these reasons, EPA continues to track these technologies and collect data about them.

Table 1
Examples of Superfund Sites Using Soil Vapor Extraction (SVE), Air Sparging (AS),
or Dual Phase Extraction (DPE)*

Name of Site	Technology	Status**	Contaminants
Fairchild Semiconductor (San Jose), CA	SVE	Completed	Volatile organic compounds (VOCs), benzene, toluene, ethylbenzene & xylene (BTEX)
Garden State Cleaners, NJ	SVE	Completed	VOCs
Defense General Supply Center, VA	SVE	Completed	VOCs
Hollingsworth Solderless, FL	SVE	Completed	VOCs
Rocky Mountain Arsenal, CO	SVE	Completed	VOCs
Lindsay Manufacturing, NE	SVE	Operational	VOCs
Applied Environmental Services, NY	SVE/AS	Operational	BTEX, VOCs, semi-volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAHs)
Wayne Reclamation and Recycling, IN	SVE/AS	Operational	VOCs, BTEX
Sand Creek Industrial, CO	SVE/DPE	Predesign	VOCs, PAHs, BTEX
Linemaster Switch Corporation, CT	SVE/DPE	In design	VOCs
Rochester Property, SC	AS	Operational	VOCs
Fairchild Air Force Base, WA	AS	Operational	VOCs, BTEX

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

*Not all waste types and site conditions are comparable. Each site must be individually investigated and tested.
 Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

**As of August 1995

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National Center for Environmental Publications and Information (NCEPI)
 P.O. Box 42419
 Cincinnati, OH 45242

- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Resources*, January 1995, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Soil Vapor Extraction Treatment Technology Resource Guide*, September 1994, EPA 542-B-94-007. A bibliography of publications and other sources of information about SVE, air sparging and other innovative treatment technologies.
- *In Situ Remediation Technology Status Report: Thermal Enhancements*, April 1995, EPA 542-K-94-009.
- *Technology Assessment of Soil Vapor Extraction and Air Sparging*, September 1992, EPA 600-R-92-173.
- *Superfund Innovative Technology Evaluation Program: Technology Profiles (7th Ed.)*, EPA 540-R-94-526.
- *A Citizen's Guide to Bioremediation*, EPA 542-F-96-007.
- WASTECH® Monograph on Vacuum Vapor Extraction, ISBN #1-883767-08-3. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: La extracción de vapores del suelo *y la aspersión de aire*

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es la extracción de vapores del suelo?

La extracción de vapores del suelo es el tratamiento innovador que se selecciona con más frecuencia para sitios comprendidos en el *Superfund*. Es un proceso relativamente sencillo que separa físicamente los contaminantes del suelo. Como su nombre lo indica, consiste en la *extracción* de contaminantes del suelo en forma de *vapor*. Por lo tanto, los sistemas de extracción de vapores del suelo sirven para retirar contaminantes que tienden a *volatizarse* o a evaporarse con facilidad. Con esta técnica se extraen compuestos orgánicos *volátiles* y algunos compuestos orgánicos *semivolátiles* de la zona no saturada del subsuelo, que está arriba de la capa freática. Por medio de un sistema de pozos subterráneos se crea un vacío y los contaminantes ascienden a la superficie en forma de vapor o gas. A menudo, además de los pozos de extracción se instalan pozos de *inyección* de aire para aumentar la corriente de aire y mejorar la tasa de remoción del contaminante. Otra ventaja de la introducción de aire en el suelo es que puede estimular la *biocorrección* de algunos contaminantes.

La extracción de vapores del suelo se conoce también como volatilización *in situ*, volatilización mejorada, aireación del suelo *in situ*, aireación forzada del suelo, remoción *in situ* por chorro de aire o extracción al vacío.

¿Qué es la aspersión de aire?

Por sí sola, la extracción de vapores del suelo no puede retirar contaminantes de la zona *saturada* del subsuelo, o sea la tierra empapada en agua que está debajo de la capa freática. En los lugares donde la contaminación está en la zona saturada, se puede usar una técnica llamada aspersión de aire junto con el sistema de extracción de vapores del suelo. La aspersión de aire consiste en introducir aire por bombeo en la zona saturada para que los contaminantes asciendan en burbujas hasta la zona no saturada, donde pueden extraerse por medio de los pozos del sistema de extracción de vapores del suelo (figura 1).

Para que la aspersión de aire dé resultado, la tierra de la zona saturada debe estar suficientemente floja como para que el aire inyectado pueda escapar fácilmente y ascender hasta la zona no saturada. Por lo tanto, la aspersión de aire actuará con mayor celeridad en lugares con suelo de grano grueso, como arena y grava.

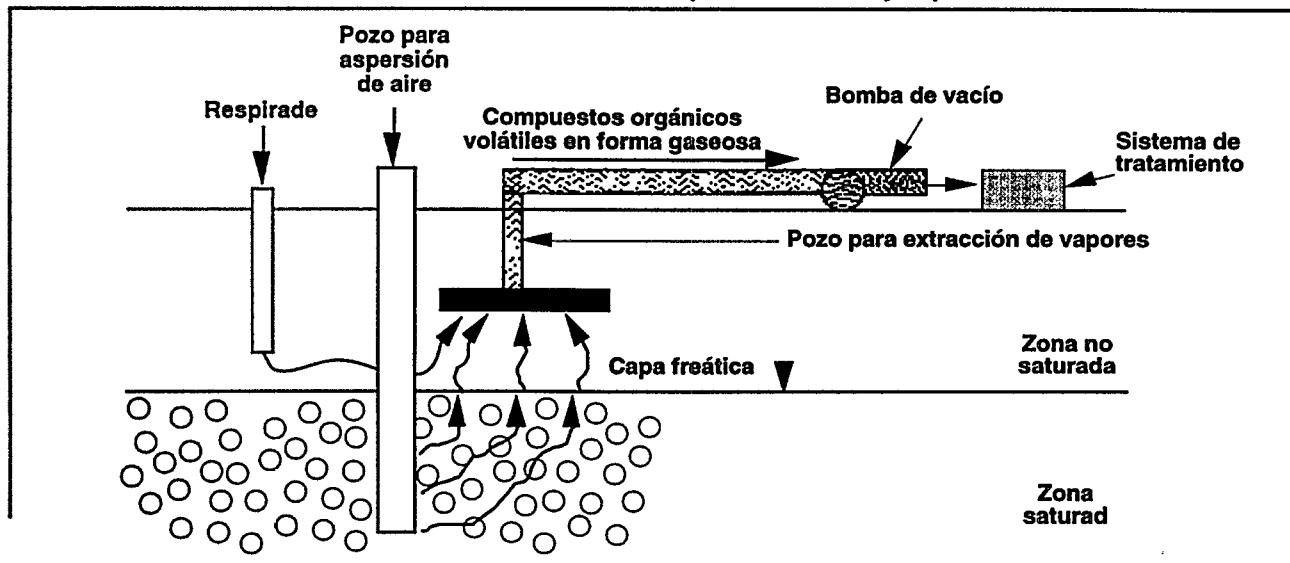
Perfil de la extracción de vapores del suelo

- Se extraen contaminantes del suelo en forma de vapor.
- Proporciona una fuente de oxígeno que puede estimular la biocorrección de algunos contaminantes.
- Es la técnica de tratamiento innovadora que más se usa.

Perfil de la aspersión de aire

- Extiende la acción de la extracción de vapores del suelo a contaminantes presentes en el agua subterránea.
- Puede acelerar la limpieza en sitios de bombeo y tratamiento.
- Proporciona una fuente de oxígeno que puede estimular la biocorrección de algunos contaminantes.

Figura 1
Sistema combinado de extracción de vapores del suelo y aspersión de aire



Igual que en el caso de la extracción de vapores del suelo, otra ventaja de la aspersión de aire es que proporciona una fuente de oxígeno que estimula la *biocorrección* de algunos contaminantes. Las medidas biocorrectivas son técnicas de tratamiento innovadoras que utilizan microorganismos que viven en el suelo o en el agua subterránea (por ejemplo, bacterias) para descomponer contaminantes en sustancias inocuas. (Las medidas biocorrectivas se explican con pormenores en otra Guía del ciudadano. Véase el recuadro "Para más información" en la página 4.) La aspersión de aire también puede ser un tratamiento rápido y eficaz para los compuestos orgánicos volátiles del agua subterránea.

¿Cómo funciona el sistema de extracción de vapores del suelo?

El primer paso para construir un sistema de extracción de vapores del suelo consiste en instalar pozos de extracción de vapor y pozos de inyección (o respiraderos) en la zona contaminada. Los pozos de inyección de aire usan compresores de aire para forzar la entrada de aire en el suelo. Los respiraderos desempeñan la misma función que los pozos de inyección, pero son pasivos: en vez de bombear aire, simplemente constituyen un pasaje para que se introduzca aire en el suelo. Cuando el aire que entra pasa por el suelo camino a los pozos de extracción, los contaminantes se evaporan de los espacios entre las partículas del suelo, son arrastrados por el aire hasta los pozos y allí se extraen.

Los pozos de extracción de vapores pueden ser verticales u horizontales. Generalmente son verticales y penetran

hasta las capas inferiores de la zona no saturada. Los vapores extraídos con este proceso por lo general son sometidos a un tratamiento de adsorción con carbón, incineración, oxidación catalítica o condensación. También se han usado otros métodos, como tratamiento biológico y oxidación ultravioleta. El tipo de tratamiento que se seleccione dependerá de los contaminantes presentes y su concentración.

La adsorción con carbón es el tratamiento que más se usa para los vapores contaminados y se puede adaptar a una amplia gama de compuestos orgánicos volátiles.

Si se proyecta y se utiliza bien, el sistema de extracción de vapores del suelo es un proceso seguro que requiere pocas tareas de mantenimiento. Hay equipo a prueba de explosiones para manejar mezclas de gases extraídos de algunos vertederos o lugares donde se ha derramado gasolina, puesto que estas mezclas podrían ser explosivas.

Extracción de vapores del suelo mejorada térmicamente. Se puede mejorar la extracción de vapores del suelo con la inyección de aire caliente o vapor en el suelo contaminado por medio de los pozos de inyección. El aire caliente o el vapor ayuda a "aflojar" algunos compuestos menos volátiles del suelo. Se han realizado demostraciones en gran escala de extracción de vapores del suelo con inyección de vapor en varios lugares. Además del aire caliente o el vapor, otra mejora de la extracción de vapores del suelo es el uso de radiofrecuencias para calentar el suelo y vaporizar o volatilizar mejor los compuestos en suelos arcillosos y

limosos. Se están realizando demostraciones del uso de radiofrecuencias.

Extracción de doble fase. La extracción de doble fase es un sistema de tratamiento similar a la extracción de vapores del suelo, pero los pozos de extracción son más profundos y llegan a la zona saturada, debajo de la capa freática. Se aplica un fuerte vacío por medio de los pozos de extracción para extraer simultáneamente agua subterránea y vapores del subsuelo. Cuando los vapores y el agua subterránea llegan a la superficie, se separan y se someten a un tratamiento. En suelos densos y arcillosos, la extracción de doble fase es más eficaz que el método corriente de extracción de vapores. Cuando la extracción de doble fase se combina con medidas biocorrectivas, aspersión de aire o bioaireación, la limpieza lleva menos tiempo.

¿En qué casos convendría usar la extracción de vapores del suelo o la aspersión de aire?

La extracción de vapores del suelo es muy eficaz para retirar compuestos orgánicos volátiles de la zona no saturada. Con la adición de un sistema de aspersión de aire, se pueden retirar contaminantes también de la zona saturada. Para ninguna de las dos técnicas se necesita excavar el suelo contaminado. (Es mejor evitar la excavación porque es costosa, levanta polvo y permite que salgan a la atmósfera contaminantes volátiles sin tratar.) Los vapores extraídos generalmente necesitan un tratamiento, pero el costo del tratamiento de los vapores y líquidos extraídos es bajo en comparación con el costo de las técnicas que requieren excavación. El equipo es relativamente fácil de instalar, se puede usar eficazmente en combinación con otras técnicas de tratamiento y es eficaz para sitios con diferentes condiciones.

¿Darán resultado estas técnicas en cualquier lugar?

La extracción de vapores del suelo y la aspersión de aire pueden ser buenas opciones para lugares contaminados con solventes, otros compuestos orgánicos volátiles (como tricloroetano, tricloroetileno, benceno, tolueno, etilbenceno y xileno) y combustibles. Como las propiedades del suelo tienen un efecto muy importante en el movimiento de los vapores del suelo, la eficacia y el diseño de sistemas de extracción de vapores del suelo y aspersión de aire dependen en gran medida de las propiedades del suelo. La extracción de vapores del suelo da mejor resultado en suelos flojos no saturados, como arena, grava y limo grueso o lecho de roca fracturado. Sin embargo, se ha usado en suelos más densos, aunque el tratamiento podría llevar más tiempo. Además, cuanta más humedad contenga el suelo, más lenta será la extracción.

¿Dónde se están usando las técnicas de extracción de vapores del suelo y aspersión de aire?

La técnica de extracción de vapores del suelo se ha usado en varios lugares con desechos peligrosos, en muchos de ellos con recursos del *Superfund*. Verona Well Field (Michigan) es uno de los sitios donde se usó la técnica de extracción de vapores del suelo con recursos del *Superfund* para tratar una zona de 2.000 m² hasta una profundidad de seis metros contaminada con tricloroetano, tetracloroetileno y una mezcla de benceno, tolueno, etilbenceno y xileno. Con este sistema se trajeron y se trajeron 20 toneladas métricas de contaminantes del lugar. El EPA estableció niveles de limpieza para 19 contaminantes del lugar y con la técnica extracción de vapores del suelo se alcanzaron las metas para todos los contaminantes. El cuadro 1 de la página 4 contiene más ejemplos de sitios donde se planea usar o se ha usado la extracción de vapores del suelo, la aspersión de aire y la extracción de doble fase con recursos del *Superfund*.

¿Qué son las técnicas de tratamiento innovadoras?

Las técnicas de tratamiento son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden alterar materiales contaminados, destruyéndolos o modificándolos, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos. Las técnicas de tratamiento innovadoras son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Algunas técnicas de tratamiento innovadoras, como la extracción de vapores del suelo y la desorción térmica, están tan difundidas que calificarlas de "innovadoras" podría parecer inadecuado. Sin embargo, siguen apareciendo variantes innovadoras de estas técnicas y el EPA no puede aún prever con certeza el tiempo que se tardará en descontaminar un sitio con estas técnicas ni el costo. Por estas razones, el EPA continúa observando su evolución y recopilando datos sobre ellas.

Cuadro 1
**Ejemplos de lugares donde se usan las técnicas de extracción de vapor del suelo,
aspersión de aire y extracción de doble fase con recursos del Superfund***

Nombre del sitio	Técnica	Situación**	Contaminantes
Fairchild Semiconductor (San Jose) (California)	EVS	Concluida	Compuestos orgánicos volátiles, benceno, tolueno, etilbenceno y xileno
Garden State Cleaners (Nueva Jersey)	EVS	Concluida	Compuestos orgánicos volátiles
Defense General Supply Center (Virginia)	EVS	Concluida	Compuestos orgánicos volátiles
Hollingsworth Solderless (Florida)	EVS	Concluida	Compuestos orgánicos volátiles
Rocky Mountain Arsenal (Colorado)	EVS	Concluida	Compuestos orgánicos volátiles
Lindsay Manufacturing (Nebraska)	EVS	En ejecución	Compuestos orgánicos volátiles
Applied Environmental Services (Nueva York)	EVS/AA	En ejecución	Benceno, tolueno, etilbenceno y xileno, compuestos orgánicos volátiles, compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos
Wayne Reclamation and Recycling (Indiana)	EVS/AA	En ejecución	Compuestos orgánicos volátiles, benceno, tolueno, etilbenceno y xileno
Sand Creek Industrial (Colorado)	EVS/EDF	Anteproyecto	Compuestos orgánicos volátiles, hidrocarburos poliaromáticos, benceno, tolueno, etilbenceno y xileno
Linemaster Switch Corp. (Connecticut)	EVS/EDF	En proyecto	Compuestos orgánicos volátiles
Rochester Property (Carolina del Sur)	AA	En ejecución	Compuestos orgánicos volátiles
Fairchild Air Force Base (Washington)	AA	En ejecución	Compuestos orgánicos volátiles, benceno, tolueno, etilbenceno y xileno

*EVS = extracción de vapores del suelo

AA = aspersión de aire

EDF = extracción de doble fase

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Hay una base de datos con más información sobre los sitios indicados en el *Annual Status Report*. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discetes. Consulte al NCEPI para más pormenores.

* No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

** Hasta agosto de 1995.

Para más información:

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, enero de 1995, EPA 542-B-95-001. **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- *Soil Vapor Extraction Treatment Technology Resource Guide*, septiembre de 1994, EPA 542-B-94-007. **Bibliografía de publicaciones y otras fuentes de información sobre la extracción de vapores del suelo, la aspersión de aire y otras técnicas de tratamiento innovadoras.**
- *In Situ Remediation Technology Status Report: Thermal Enhancements*, abril de 1995, EPA 542-K-94-009.
- *Technology Assessment of Soil Vapor Extraction and Air Sparging*, septiembre de 1992, EPA 600-R-92-173.
- *Superfund Innovative Technology Evaluation Program: Technology Profiles (7th Ed.)*, EPA 540-R-94-526.
- *A Citizen's Guide to Bioremediation*, EPA 542-F-96-007.
- *WASTECH® Monograph on Vacuum Vapor Extraction*, ISBN #1-883767-08-3. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Soil Washing

Technology Innovation Office

Technology Fact Sheet

What is soil washing?

Soil washing is a technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils. This scrubbing removes hazardous contaminants and concentrates them into a smaller volume. Hazardous contaminants tend to bind, chemically or physically, to silt and clay. Silt and clay, in turn, bind to sand and gravel particles. The soil washing process separates the contaminated fine soil (silt and clay) from the coarse soil (sand and gravel). When completed, the smaller volume of soil, which contains the majority of the fine silt and clay particles, can be further treated by other methods (such as incineration or bioremediation) or disposed of according to state and federal regulations. The clean, larger volume of soil is not toxic and can be used as backfill.

How does soil washing work?

A simplified drawing of the soil washing process is illustrated in Figure 1 on page 2. The equipment is transportable so that the process can be conducted at the site. The first step of the process is to dig up the contaminated soil and move it to a staging area

where it is prepared for treatment. The soil is then sifted to remove debris and large objects, such as rocks. The remaining material enters a soil scrubbing unit, in which the soil is mixed with a washing solution and agitated. The washing solution may be simply water or may contain additives, like detergent, which remove the contaminants from the soil. This process is very similar to washing laundry. The washwater is drained out of the soil scrubbing unit and the soil is rinsed with clean water. The larger scale soil washing equipment presently in use can process over 100 cubic yards of soil per day.

The heavier sand and gravel particles in the processed soil settle out and are tested for contaminants. If clean, this material can be used on the site or taken elsewhere for backfill. If traces of contaminants are still present, the material may be run through the soil washer again or collected for alternate treatment or off-site disposal. Off-site disposal may be regulated by the Resource Conservation Recovery Act (RCRA) or the Toxic Substance Control Act (TSCA).

A Quick Look at Soil Washing

- Separates fine-grained particles (silt and clay) from coarse-grained particles (sand and gravel).
- Significantly reduces the volume of contaminated soil.
- Is a relatively low-cost alternative for separating waste and minimizing volume required for subsequent treatment.
- Is a transportable technology that can be brought to the site.

The contaminated silt and clay in the washwater settle out and are then separated from the washwater. The washwater, which now also contains contaminants, is treated by wastewater treatment processes so it can be recycled for further use. As mentioned earlier, the washwater may contain additives, some of which may interfere with the wastewater treatment process. If this is the case, the additives must be removed or

neutralized by "pretreatment" methods before the washwater goes to wastewater treatment.

Once separated from the washwater, the silt and clay are tested for contaminants. If all the contaminants were transferred to the washwater and the silt and clay are clean, they can be used at the site or taken elsewhere for use as backfill. If still contaminated, the material may be run through the soil washing process again, or collected for alternate treatment or off-site disposal in a permitted RCRA or TSCA landfill.

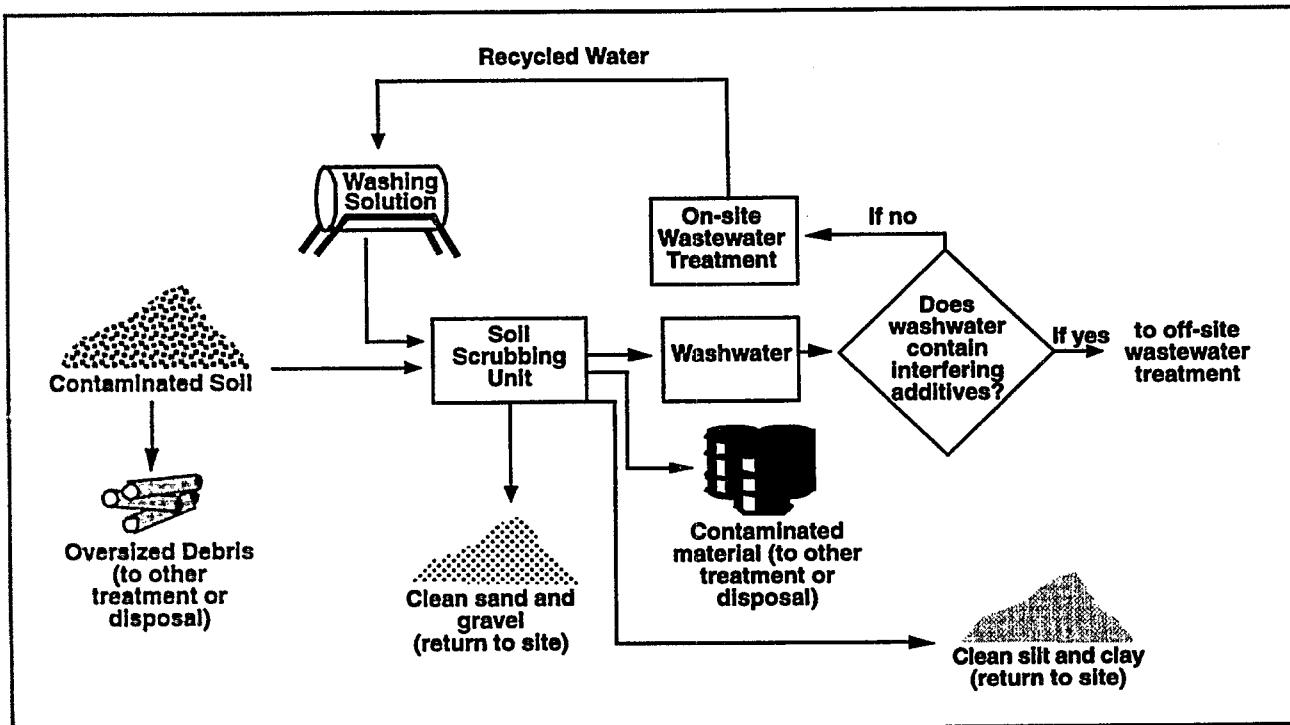
Not All Soil Is Created Equal

Soil is comprised of fine-grained (silt and clay) and coarse-grained (sand and gravel) particles, organic material (decayed plant and animal matter), water, and air. Contaminants tend to readily bind, chemically or physically, to silt, clay, and organic material. Silt, clay, and organic material, in turn, bind physically to sand and gravel. When the soil contains a large amount of clay and organic material, the contaminants attach more easily to the soil and, therefore, are more difficult to remove than when a small amount of clay and organic material is present.

Why consider soil washing?

Soil washing can be used as a technology by itself, but is often used in combination with other treatment technologies. Perhaps the principal use of soil washing is as a *volume reduction* technique in which the contaminants are concentrated in a relatively small mass of material. The larger the percentage of coarse sand and gravel in the material to be processed (which can be cleaned and perhaps returned to the site), the more cost-effective the soil washing application will be.

Figure 1
The Soil Washing Process



Ideally, the soil washing process would lead to a volume reduction of about 90% (which means only 10% of the original volume would require further treatment). Wastes with a high percentage of fine silt and clay will require a larger quantity of material to go on to subsequent, more expensive treatment. These soils may not be good candidates for soil washing.

Soil washing is used to treat a wide range of contaminants, such as metals, gasoline, fuel oils, and pesticides. There are several advantages to using this technology. Soil washing:

- Provides a closed system that remains unaffected by external conditions. This system permits control of the conditions (such as the pH level and temperature) under which the soil particles are treated.
- Allows hazardous wastes to be excavated and treated on-site.
- Has the potential to remove a wide variety of chemical contaminants from soils.
- Is cost-effective because it can be employed as a pre-processing step, significantly reducing the quantity of material that would require further treatment by another technology. It also creates a more uniform material for subsequent treatment technologies.

Will soil washing work at every site?

Soil washing works best when the soil does not contain a large amount of silt or clay. In some cases, soil washing is best applied in combination with other treatment technologies, rather than as a technology by itself.

Removal of contaminants can often be improved during the soil washing process by adding chemical additives to the washwater. However, the presence of these additives may cause some difficulty in the treatment of the used wastewater and the disposal of residuals from the washing process. Costs of handling and managing the additives have to be weighed against the amount of improvements in the performance of the soil washing process.

Where has soil washing been used?

At the King of Prussia site in New Jersey, soil washing was used to remove metal contamination such as chromium, copper, mercury, and lead from 19,000 tons of soil and sludge at a former industrial waste reprocessing facility. The soil washing process was able to clean the materials to meet clean-up goals for eleven metals. For example, chromium levels went from 8,000 milligrams chromium per kilogram of soil (mg/kg) to 480 mg/kg. Table 1 on page 4 lists some of the Superfund sites where soil washing has been selected.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so that they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste. *Innovative treatment technologies* are those that have been tested, selected, or used for treatment of hazardous waste or contaminated materials but still lack well-documented cost and performance data under a variety of operating conditions.

Table 1
Examples of Superfund Sites Where Soil Washing Has Been Selected *

Name of Site	Status**	Medium	Contaminants
Myers Property, NJ	In design	Soil, sediment	Metals
Vineland Chemical, NJ	In design	Soil	Metals
GE Wiring Devices, PR	In design	Soil, sludge	Metals
Cabot Carbon/Koppers, FL	In design	Soil	Semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), metals
Whitehouse Waste Oil Pits	Predesign	Soil, sludge	Volatile organic compounds (VOCs), PCBs, PAHs, metals
Cape Fear Wood Preserving Moss American, WI	Design complete	Soil	PAHs, metals
Arkwood, AR	Predesign	Soil	PAHs
	In design	Soil, sludge	SVOCs, dioxins, PAHs

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** As of August 1995

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Physical/Chemical Treatment Technology Resource Guide*, EPA 542-B-94-008. A bibliography of publications and other sources of information about soil washing and other innovative treatment technologies.
- *Engineering Bulletin: Soil Washing Treatment*, PB91-228056/XAB.
- *Abstracts of Remediation Case Studies*, EPA 542-R-95-001.
- WASTECH® Monograph on Soil Washing/Soil Flushing, ISBN #1-883767-03-2. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: El lavado del suelo

Oficina de Innovaciones

Ficha tecnológica

¿Qué es el lavado del suelo?

El lavado del suelo es una técnica que consiste en el uso de líquidos (generalmente agua, combinada a veces con aditivos químicos) y un procedimiento mecánico para depurar el suelo. Con este procedimiento se retiran contaminantes peligrosos y se los concentra, reduciendo su volumen. Los contaminantes peligrosos tienden a unirse en forma química o física al limo y la arcilla, materiales que, a su vez, se unen a la arena y a partículas de grava. En el procedimiento de lavado del suelo se separa la tierra fina contaminada (limo y arcilla) de la tierra gruesa (arena y grava). Una vez concluido el procedimiento, la tierra de volumen más reducido, que contiene la mayoría de las partículas finas de limo y arcilla, puede ser sometida a un tratamiento ulterior con otros métodos (como incineración o medidas biocorrectivas) o se puede eliminar de conformidad con las normas federales y estatales. La tierra más limpia, de mayor volumen, no es tóxica y se puede usar como relleno.

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Durante el procedimiento, las partículas de grava y de arena más pesadas se asientan y son sometidas a pruebas para detectar contaminantes. Si están limpias, este material se puede usar en el sitio o llevarse a otro lugar para usarlo como relleno. Si todavía quedan vestigios de contaminantes, se puede someter el material a otro ciclo de lavado, recogerlo para aplicarle un tratamiento diferente o

Perfil del lavado del suelo

- Se separan las partículas finas (limo y arcilla) de las partículas gruesas (arena y grava).
- Reduce considerablemente la cantidad de tierra contaminada.
- Es una alternativa con un costo relativamente bajo para separar los desechos y reducir al mínimo la cantidad de desechos que requieren un tratamiento ulterior.
- Se usa equipo portátil que se puede llevar hasta el lugar de las operaciones.

eliminarlo en otro lugar. Este último método podría estar reglamentado por la Ley de Conservación y Recuperación de Recursos o la Ley de Control de Sustancias Tóxicas.

El limo y la arcilla contaminados que están en el agua del lavado se asientan y se separan del agua del lavado. Como el agua del lavado ahora contiene contaminantes, es sometida a un

No todos los suelos fueron creados iguales

La tierra del suelo se compone de partículas finas (limo y arcilla) y partículas gruesas (arena y grava), material orgánico (plantas en estado de descomposición y materia animal), agua y aire. Los contaminantes tienden a unirse fácilmente, en forma química o física, al limo, la arcilla y el material orgánico. El limo, la arcilla y el material orgánico, a su vez, se unen físicamente a la arena y la grava. Cuando el suelo contiene una gran cantidad de arcilla y material orgánico, los contaminantes se unen más fácilmente a la tierra y, por lo tanto, son más difíciles de separar que cuando hay poca arcilla y material orgánico.

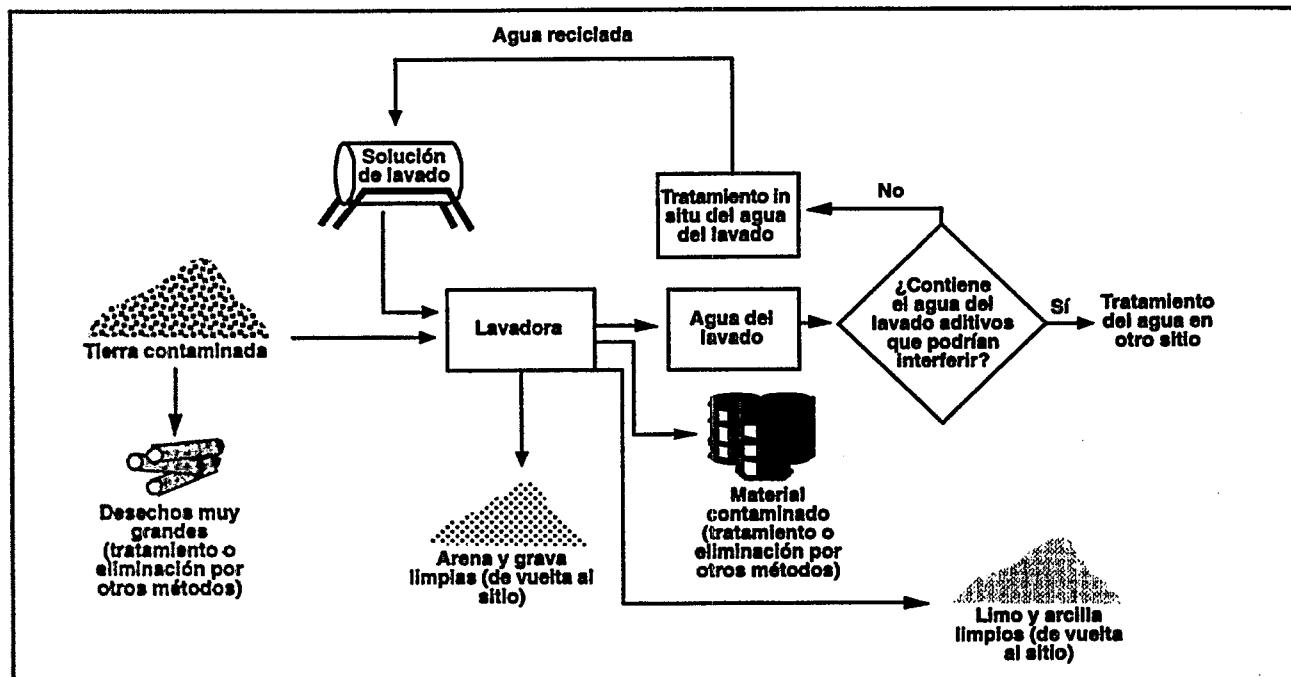
tratamiento a fin de que se pueda reciclar para otros usos. Como ya se dijo, el agua de lavado podría contener aditivos, algunos de los cuales podrían interferir en el tratamiento. En ese caso, hay que retirar los aditivos o neutralizarlos con un tratamiento preliminar.

Después de separar el limo y la arcilla del agua del lavado, se los somete a una prueba para determinar si contienen contaminantes. Si todos los contaminantes pasaron al agua del lavado y el limo y la arcilla están limpios, el limo y la arcilla se pueden usar en el sitio o se pueden llevar a otro lugar para usarlos como relleno. Si el material todavía está contaminado, se puede someter a otro ciclo de lavado, recogerlo para aplicarle un tratamiento diferente o eliminarlo en un vertedero autorizado por la Ley de Conservación y Recuperación de Recursos o la Ley de Control de Sustancias Tóxicas.

¿En qué casos convendría usar la técnica de lavado del suelo?

El lavado del suelo se puede usar por sí solo, pero a menudo se usa combinado con otras técnicas de

Figura 1. El proceso de lavado del suelo



tratamiento. El uso principal del lavado del suelo tal vez sea como técnica para *reducir el volumen*, concentrando los contaminantes en una masa relativamente pequeña de material. Cuanto mayor sea el porcentaje de arena gruesa y grava en el material que deba tratarse (que se puede limpiar y quizás llevar de vuelta al sitio), más eficaz será el lavado del suelo en función del costo.

Idealmente, el proceso de lavado del suelo reduciría el volumen en un 90% (lo cual significa que sólo el 10% del volumen original necesitaría tratamiento ulterior). Si los desechos tienen un alto porcentaje de limo fino y arcilla, una parte mayor del material deberá ser sometida a otro tratamiento subsiguiente más costoso. Estos suelos tal vez no sean buenos candidatos para un lavado.

El lavado del suelo se usa para tratar una amplia gama de contaminantes, como metales, gasolina, fuel-oil y plaguicidas. El uso de esta técnica presenta varias ventajas:

- Crea un sistema cerrado que no es afectado por condiciones externas. Este sistema permite controlar las condiciones (como el pH y la temperatura) en las cuales se tratan las partículas del suelo.
- Permite excavar los desechos peligrosos y tratarlos *in situ*.
- Ofrece la posibilidad de retirar una gran variedad de contaminantes del suelo.
- Es eficaz en función del costo porque puede usarse como tratamiento preliminar, reduciendo considerablemente la cantidad de material que necesitaría tratamiento ulterior con otro método.

Además, produce un material más uniforme al cual se aplicarán otras técnicas de tratamiento.

¿Dará resultado el lavado del suelo en cualquier lugar?

Con el lavado del suelo se obtiene un resultado óptimo cuando el suelo no contiene mucho limo o arcilla. En algunos casos, lo mejor es combinar el lavado del suelo con otras técnicas de tratamiento, en vez de usarlo por sí solo.

A menudo se pueden retirar mejor los contaminantes durante el proceso de lavado del suelo añadiendo aditivos químicos al agua del lavado. Sin embargo, la presencia de estos aditivos podría dificultar el tratamiento del agua del lavado usada y la eliminación de residuos del lavado. Hay que tener en cuenta el costo de la manipulación y el uso de aditivos en función de la mejora que se logrará en la eficacia del proceso de lavado del suelo.

¿Dónde se ha usado la técnica de lavado del suelo?

En un lugar de Nueva Jersey que se llama King of Prussia se usó la técnica de lavado del suelo para retirar metales contaminantes tales como cromo, cobre, mercurio y plomo de 19.000 toneladas de tierra y fango residual de una antigua instalación de transformación de desechos industriales. Con este procedimiento se lavaron los materiales para que cumplieran las metas de limpieza correspondientes a once metales. Por ejemplo, el nivel de cromo bajó de 8.000 mg por kilogramo de tierra (mg/kg) a 480 mg/kg. El cuadro 1 de la página 4 contiene una lista de algunos sitios donde se utilizó la técnica de lavado del suelo con recursos del *Superfund*.

¿Qué son las técnicas de tratamiento innovadoras?

Las técnicas de tratamiento son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden alterar materiales contaminados, destruyéndolos o modificándolos, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos. Las técnicas de tratamiento innovadoras son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Cuadro 1
Ejemplos de sitios para los cuales se ha seleccionado la técnica de lavado del suelo con recursos del Superfund*

Nombre del sitio	Situación**	Medio	Contaminantes
Myers Property (Nueva Jersey)	En proyecto	Tierra, sedimento	Metales
Vineland Chemical (Nueva Jersey)	En proyecto	Tierra	Metales
GE Wiring Devices (Puerto Rico)	En proyecto	Tierra, fango	Metales
Cabot Carbon/Koppers (Florida)	En proyecto	Tierra	Compuestos orgánicos semivolátiles, hidrocarburos poliaromáticos, metales
Whitehouse Waste Oil Pits	Anteproyecto	Tierra, fango	Compuestos orgánicos volátiles, bifenilos policlorados, hidrocarburos poliaromáticos, metales
Cape Fear Wood Preserving	Proyecto concluido	Tierra	Hidrocarburos poliaromáticos, metales
Moss American, (Wisconsin)	Anteproyecto	Tierra	Hidrocarburos poliaromáticos
Arkwood, (Arkansas)	En proyecto	Tierra, fango	Compuestos orgánicos semivolátiles, dioxina, hidrocarburos poliaromáticos

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.), EPA 542-R-95-008*. Hay una base de datos con más información sobre los sitios indicados en el Annual Status Report. La base de datos se puede recibir gratis por computadora; está en la cartelería electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discquetes. Consulte al NCEPI para más pormenores.

* No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

** Hasta agosto de 1995.

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- Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources, EPA 542-B-95-001. **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- Physical/Chemical Treatment Technology Resource Guide, EPA 542-B-94-008. **Bibliografía de publicaciones y otras fuentes de información sobre el lavado del suelo y otras técnicas de tratamiento innovadoras.**
- Engineering Bulletin: Soil Washing Treatment, PB91-228056/XAB.
- Abstracts of Remediation Case Studies, EPA 542-R-95-001.
- WASTECH® Monograph on Soil Washing/Soil Flushing, ISBN #1-883767-03-2. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Solvent Extraction

Technology Innovation Office

Technology Fact Sheet

What Is solvent extraction?

Solvent extraction is a treatment technology that uses a *solvent* (a fluid that can dissolve another substance) to separate or remove hazardous organic contaminants from sludges, sediments, or soil. (*Sludge* is a mud-like material produced from industrial or sewage waste, and *sediment* is fine-grained rock and mineral fragments which have settled to the bottom of a water body such as a river or lake.) Solvent extraction does not destroy contaminants. It concentrates them so they can be more easily recycled or destroyed by another technology.

When the soil enters an extractor (a tank where the contaminated soil is mixed with the solvent), the soil is separated into three components, or "fractions." The three fractions are: solvent with dissolved contaminants, solids, and water. Different contaminants concentrate into different fractions. For example, polychlorinated biphenyls (PCBs) concentrate in the contaminated solvent, while metals are left behind in the solids and water. Each fraction can be individually treated or disposed of more cost effectively. A simplified drawing of the solvent extraction process is illustrated in Figure 1 on page 2.

The solvent extraction process involves five steps:

- Preparation (sorting the contaminated material)
- Extraction
- Separation of concentrated contaminants from solvent
- Removal of residual solvent
- Contaminant recovery, recycling, or further treatment.

How does it work?

Treatment of contaminated *soil* is discussed in this guide, but the method would be basically the same for treatment of sludges or sediments.

The entire process is conducted on-site and begins by excavating the contaminated soil and moving it to a staging area where it is prepared for treatment. The soil is then sifted to remove debris and rocks. The soil may be processed in either a batch, a semi-batch, or a continuous mode. In the semi-batch mode, the material is cycled through the extraction unit in increments. If the soil is processed continuously, it may need to be made more fluid so it can move easily through the process by pumping. This is accomplished by adding water or, in the case of oily sludges, adding solvents to the material.

A Quick Look at Solvent Extraction

- Separates contaminants so they may be treated individually.
- Is a transportable technology that can be brought to the site.
- Reduces the volume of contaminated material.
- Processes up to 125 tons of waste per day.
- Is designed to operate without air emissions.

The soil is placed in the extractor. Extractors can vary in size. Some process 25 tons per day, while others may treat over 125 tons daily and require setup areas of 1,500 to 10,000 square feet or more. (For comparison, a tennis court covers about 4,000 square feet.) The solvent is added to the extractor, and the soil and solvent are mixed together. Consequently, the organic contaminants dissolve into the solvent.

A number of factors control the speed with which contaminants are dissolved from the soil. Some of these controlling factors include temperature, moisture content, and the level of contamination. Each is critical to the design of the treatment. Treatability studies performed in a laboratory are required to determine how much solvent is needed and how long the material must remain in the extractor in order to assure maximum effectiveness. Since some solids may contain contaminants that require more than one cycle in the extractor, this step of the process may need to be repeated.

The extraction process produces three fractions which require separation:

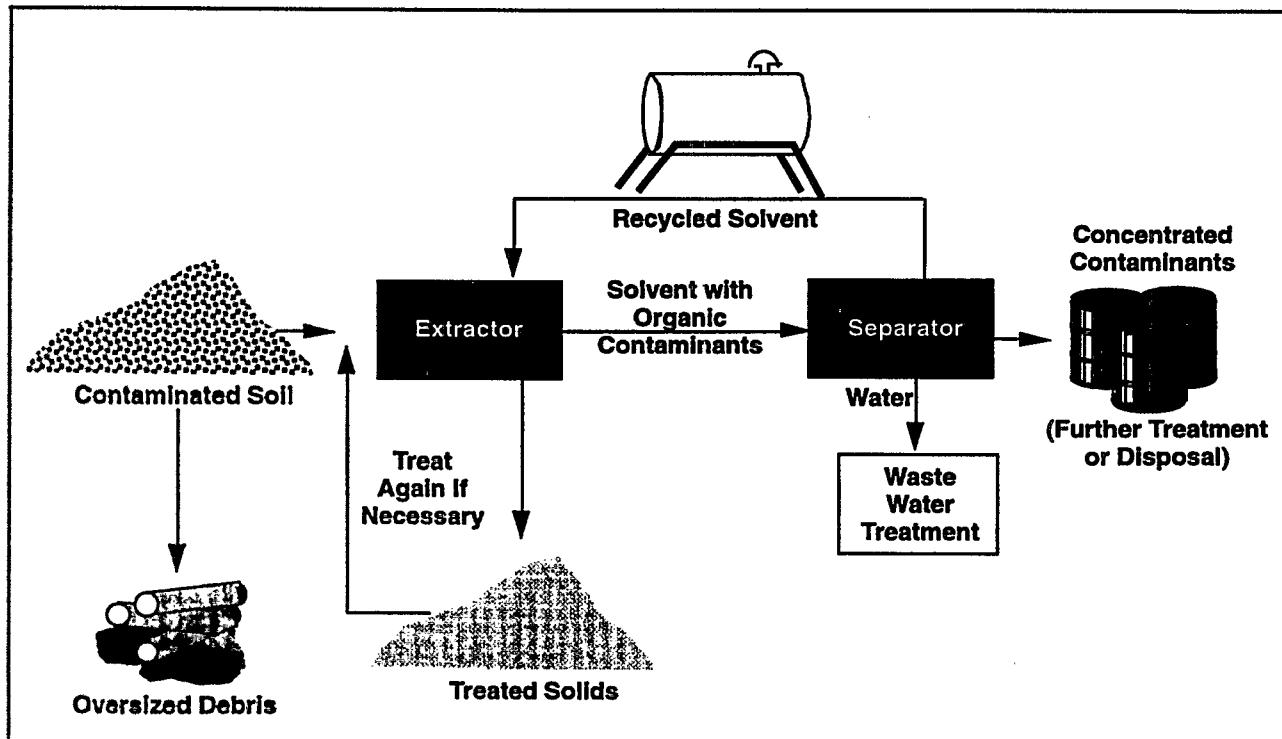
- The contaminated solvent mixture.
- The treated soil which, depending on the concentrations of contaminants present, may require a repeat cycle or further treatment by some other technique.

- The water, which must be analyzed to determine if further treatment is necessary before discharge to either a publicly-owned treatment plant or other approved discharge area.

The separation process occurs next. The contaminants are separated from the solvent either by changing the pressure and temperature, by using a second solvent to pull the first solvent out of the solvent/contaminant mixture, or by other physical separation processes. At the completion of this step, concentrated contaminants result. Concentrated contaminants are removed during the separation process, and the solvent is sent to a holding tank for reuse. The contaminants are then analyzed to determine their suitability for recycle/reuse, or need for further treatment before disposal.

Solvent extraction units are designed to operate without giving off contaminated vapors or *air emissions*. However, at some sites, air emissions could occur during excavation or preparation of contaminated soil. If air emissions exceed levels allowed by law, waste preparation and handling procedures at the site must be modified.

Figure 1
The Solvent Extraction Process



Why consider solvent extraction?

Solvent extraction can be both an effective and cost efficient process for separating hazardous contaminants from non-hazardous materials and concentrating the hazardous materials for further treatment. Because the contaminants are separated, the treatment selected can be targeted to the contaminant. As a result of solvent extraction, some contaminants may be recycled or reused in manufacturing, thus minimizing disposal requirements. The process has been effective in removing organic contaminants from paint wastes, synthetic rubber process wastes, coal tar wastes, drilling muds, wood treating wastes, pesticide/insecticide wastes, and oily wastes.

What contaminants can it treat?

Solvent extraction has been shown to be effective in treating sediments, sludges, and soils containing primarily organic contaminants, such as polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), halogenated solvents (solvents containing halogens, which are bromine, chlorine, or iodine), and petroleum wastes. These contaminants typically come from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving manufacturing processes. Table 1 lists the different solvents that are used. This technology is generally not used for removing inorganics (*i.e.*, acids, bases, salts, and heavy metals) as these materials do not readily dissolve in most solvents. Other treatment methods exist to treat these contaminants.

Will it work at every site?

Solvent extraction can be effective at separating hazardous organic contaminants from some contaminated soils, sludges, and sediments. It does not reduce the toxicity of the contaminants and, therefore, the final product of the process (the concentrated *residuals*) still require treatment or disposal. Some of the limitations of this technology include:

Table 1
Solvents Used in the Solvent Extraction Process

Liquid Carbon Dioxide
Propane
Butane
Triethylamine
Acetone
Methanol
Hexane
Dimethyl Ether

- If the waste contains detergents or strong acids or bases, solvent extraction may not be effective. Their presence can reduce the amount of contamination removed and slow the speed with which they are removed.
- The presence of lead and other inorganics may interfere with the removal of organic materials.
- Implementation can require complex engineering considerations. For example, some systems include compressed butane and propane, which require strict management to prevent them from vaporizing and igniting.
- Extensive pretreatment of the waste may be required to remove or break up large clumps.

Where is solvent extraction being used?

Table 2 on page 4 lists some Superfund sites at which solvent extraction has been selected as a treatment method. In addition to using this technology at Superfund sites, solvent extraction is commonly used by manufacturers in their day-to-day operations. Since solvents are expensive raw materials that can be reused, manufacturers, such as the dry cleaning and perfume industries, regularly recycle the solvents used in their manufacturing processes.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to destroy or change contaminated materials so they are less hazardous or not hazardous at all. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties, or by immobilizing the waste.

Innovative treatment technologies are those that have been tested, selected, or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

Table 2
Examples of Superfund Sites Using Solvent Extraction *

Name of Site	Status**	Type of Facility	Contaminants
Carolina Transformer, NC	In design	Transformer repair	Polychlorinated biphenyls (PCBs)
United Creosoting, TX	In design	Wood preserving	Polyaromatic hydrocarbons (PAHs)
Arrowhead Refinery Co., MN	Operational	Waste oil refining	Volatile organic contaminants (VOCs), PCBs, PAHs, metals, solvents
Idaho Nat'l Engineering Lab (Pit 9), ID	In design	Nuclear research	VOCs, PCBs

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

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** As of August 1995

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- *Physical/Chemical Treatment Technology Resource Guide*, EPA 542-B-94-008. A bibliography of publications and other sources of information about soil flushing, soil washing, solvent extraction, and other innovative treatment technologies.
- *Engineering Bulletin, Solvent Extraction*, EPA 540-S-94-503, PB94-190477.
- *EPA Engineering Issue: Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment*, EPA 540-S-93-506, PB94-144250/XAB.
- *WASTECH® Monograph on Solvent/Chemical Extraction*, ISBN #1-883767-05-9. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: La extracción con solventes

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es la extracción con solventes?

La extracción con solventes es una técnica de tratamiento que consiste en usar un solvente (un líquido capaz de disolver otra sustancia) para separar o retirar contaminantes orgánicos peligrosos de fangos residuales, sedimentos o tierra. (El fango residual es un material parecido al barro que se forma a partir de desechos industriales o cloacales; los sedimentos son fragmentos de rocas y minerales de grano fino que se han depositado en el fondo de una masa de agua, como un río o un lago.) La extracción con solventes no destruye los contaminantes, sino que los concentra para que sea más fácil reciclarlos o destruirlos con otra técnica.

Cuando la tierra entra en el extractor (tanque donde la tierra contaminada se mezcla con el solvente), se separa en tres componentes o "fracciones": solvente con contaminantes disueltos, sólidos y agua. Los distintos contaminantes se concentran en fracciones diferentes. Por ejemplo, los bifenilos policlorados se concentran en el solvente contaminado, mientras que los metales quedan en los sólidos y en el agua. Cada fracción, individualmente, puede ser tratada o eliminada en una forma más eficaz en función del costo. La figura 1 de la página 2 presenta un esquema del proceso de extracción con solventes.

El proceso de extracción con solventes abarca cinco pasos:

- Preparación (clasificación del material contaminado)
- Extracción
- Separación de contaminantes concentrados del solvente
- Remoción del solvente residual
- Recuperación de los contaminantes, reciclaje o tratamiento ulterior.

¿Cómo funciona?

En esta guía se explica el tratamiento de tierra contaminada, pero para tratar fangos residuales o sedimentos se usa básicamente el mismo método.

Todo el proceso se realiza in situ. Comienza con la excavación del suelo contaminado y su traslado a un lugar de tránsito donde se prepara la tierra para el tratamiento, pasándola por una criba para separar desechos de gran tamaño y piedras. La tierra puede tratarse por tandas, por semitandas o en forma continua. En la modalidad de semitandas, el material pasa por el extractor en incrementos. Si se trata la tierra en forma continua, tal vez sea necesario hacerla más fluida para que pueda pasar fácilmente por el proceso mediante bombeo. Para eso se le agrega agua o, en el caso de fangos oleosos, solventes.

Perfil de la extracción con solventes

- Se separan los contaminantes para que puedan ser tratados individualmente.
- Se usa equipo portátil que se puede llevar al sitio de la limpieza.
- Reduce la cantidad de material contaminado.
- Se pueden tratar hasta 125 toneladas de desechos por día.
- No produce emisiones en la atmósfera.

Se coloca la tierra en el extractor. Los extractores son de distinto tamaño. Algunos tratan 25 toneladas por día, mientras que otros tienen capacidad para más de 125 toneladas diarias y ocupan de 140 a 1.000 metros cuadrados o más. (En comparación, una cancha de tenis ocupa alrededor de 370 metros cuadrados.) Se añade solvente al extractor y se mezcla la tierra con el solvente. Los contaminantes orgánicos se disuelven en el solvente.

La velocidad con que se disuelven los contaminantes del suelo depende de varios factores, como la temperatura, el contenido de humedad y el grado de contaminación, entre otros. Cada uno de estos factores es decisivo para la concepción del tratamiento. Es necesario realizar estudios de tratabilidad en un laboratorio para determinar la cantidad de solvente que se necesita y el tiempo que el material debe permanecer en el extractor a fin de garantizar la máxima eficacia posible. Como algunos sólidos podrían contener contaminantes que deben pasar más de una vez por el extractor, es posible que haya que repetir este paso del proceso.

El proceso de extracción produce tres fracciones que requieren separación:

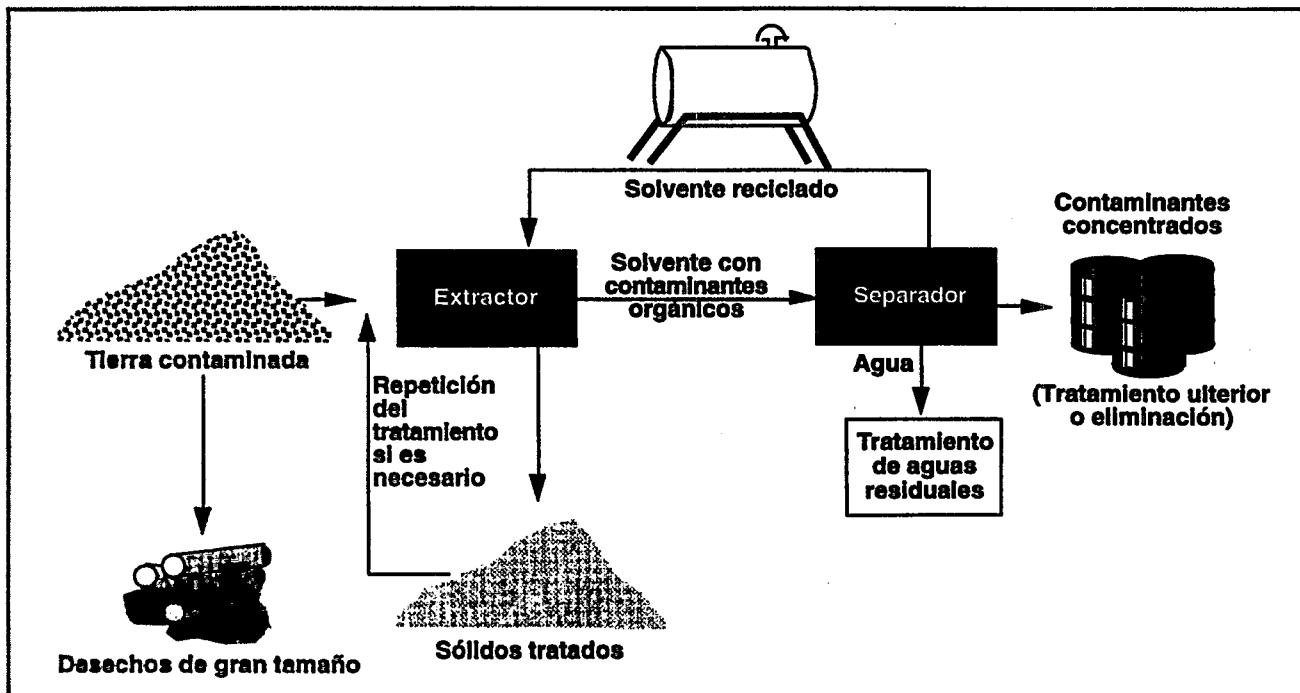
- La mezcla de solvente contaminado.
- La tierra tratada, que, según la concentración de contaminantes presentes, podría requerir una repetición del ciclo o tratamiento ulterior con otra técnica.

- El agua, que debe analizarse para determinar si necesita tratamiento ulterior antes de verterla en una planta de tratamiento pública o en otra zona de descarga aprobada.

Después viene el procedimiento de separación. Se separan los contaminantes del solvente cambiando la presión y la temperatura, usando otro solvente para sacar el primero de la mezcla de solvente y contaminantes o con otro procedimiento de separación física. Cuando concluye este paso, lo que queda es contaminantes concentrados, que se retiran durante el procedimiento de separación, y el solvente pasa a un tanque para su reutilización. Después se analizan los contaminantes para determinar si son aptos para reciclaje o reutilización o si necesitan otro tratamiento antes de su eliminación.

Los extractores de solventes no emiten vapores contaminados, es decir, no producen *emisiones en la atmósfera*. Sin embargo, en algunos lugares podría haber emisiones durante la excavación o preparación de suelos contaminados. Si las emisiones exceden los límites permitidos por ley, hay que modificar los procedimientos utilizados en ese sitio para la preparación y el manejo de desechos.

Figura 1
El proceso de extracción con solventes



¿En qué casos convendría usar la técnica de extracción con solventes?

La extracción con solventes es un proceso que puede resultar eficaz y eficiente en función del costo para separar contaminantes peligrosos de materiales no peligrosos y concentrar los materiales peligrosos para un tratamiento ulterior. Como se separan los contaminantes, se puede seleccionar el método de tratamiento más apropiado para cada uno. Tras la extracción con solventes, algunos contaminantes pueden reciclarse o reutilizarse en la industria manufacturera, reduciendo al mínimo la necesidad de eliminarlos. Este proceso ha resultado eficaz para retirar contaminantes orgánicos de desechos de pintura, desechos del proceso de fabricación de goma sintética, desechos de alquitrán de hulla, barro extraído en perforaciones, desechos del tratamiento de la madera, plaguicidas e insecticidas desechados y desechos oleosos.

¿Qué contaminantes se pueden tratar con esta técnica?

Se ha comprobado que la extracción con solventes es eficaz para tratar sedimentos, fangos residuales y tierra que contienen principalmente contaminantes orgánicos, como bifenilos policlorados, compuestos orgánicos volátiles, solventes halogenados (solventes que contienen halógenos, o sea bromo, cloro o yodo) y desechos del petróleo. Generalmente, estos contaminantes provienen del desengrasado de metales, la limpieza de tableros de circuitos impresos, gasolina y procesos de fabricación de conservantes de la madera. El cuadro 1 presenta una lista de los solventes que se usan. Esta técnica por lo general no se usa para extraer contaminantes inorgánicos (es decir, ácidos, bases, sales y metales pesados), ya que estos materiales no se disuelven fácilmente en la mayoría de los solventes. Para estos contaminantes existen otros métodos de tratamiento.

¿Dará resultado esta técnica en cualquier lugar?

La extracción con solventes puede dar resultado para separar contaminantes orgánicos peligrosos de algunos tipos de fangos residuales, sedimentos y tierra. No reduce

Cuadro 1
Solventes utilizados en el proceso de extracción con solventes

- | | |
|------------------------------|-------------------|
| • Dióxido de carbono líquido | • Propano |
| • Butano | • Trietilamina |
| • Acetona | • Metanol |
| • Hexano | • Éter dimetílico |

la toxicidad de los contaminantes; por consiguiente, el producto final del proceso (los *residuos* concentrados) debe ser sometido a un tratamiento ulterior o eliminado. Algunas de las limitaciones de esta técnica son las siguientes:

- La presencia de plomo y de otros contaminantes inorgánicos podría interferir en la extracción de materiales orgánicos.
- La aplicación de la técnica podría implicar complejas consideraciones técnicas. Por ejemplo, algunos sistemas usan butano y propano comprimidos, que exigen un manejo estricto para evitar que se vaporicen y se prendan fuego.
- Podría ser necesario un tratamiento preliminar extenso de los desechos para sacar o desmenuzar los terrenos grandes.

¿Dónde se está usando la extracción con solventes?

El cuadro 2 de la página 4 contiene una lista de algunos lugares para los cuales se ha seleccionado la extracción con solventes como método de tratamiento con recursos del *Superfund*. Además de los sitios comprendidos en el *Superfund*, la extracción con solventes se usa comúnmente en las operaciones cotidianas de la industria manufacturera. Como los solventes son materia prima costosa que se puede reutilizar, los fabricantes, como en la industria de los perfumes y de la limpieza en seco, reciclan regularmente los solventes que usan en sus procesos de fabricación.

¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden destruir o modificar materiales contaminados, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos.

Las *técnicas de tratamiento innovadoras* son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Cuadro 2

Ejemplos de sitios donde se usa el *Superfund* para aplicar la técnica de extracción con solventes*

Nombre del sitio	Situación**	Tipo de instalación	Contaminantes
Carolina Transformer (Carolina del Norte)	En proyecto	Reparación de transformadores	Bifenilos policlorados
United Creosoting (Texas)	En proyecto	Conservación de madera	Hidrocarburos poliaromáticos
Arrowhead Refinery Co. (Minnesota)	En ejecución	Refinería de petróleo desechado	Compuestos orgánicos volátiles, bifenilos policlorados, hidrocarburos poliaromáticos, metales, solventes
Idaho National Engineering Lab (Pit 9) (Idaho)	En proyecto	Investigaciones nucleares	Compuestos orgánicos volátiles, bifenilos policlorados

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del *Superfund*, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.), EPA 542-R-95-008*. Hay una base de datos con más información sobre los sitios indicados en el *Annual Status Report*. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discetes. Consulte al NCEPI para más pormenores.

* No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

** Hasta agosto de 1995.

Para más información:

Las publicaciones con las siglas "EPA" en el número de documento se proporcionan gratis. Envíe su pedido por fax al 513-489-8695 o escriba al NCEPI, cuya dirección figura más abajo. Si al NCEPI no le quedan más ejemplares de alguno de estos documentos, puede dirigirse a otras fuentes.

National Center for Environmental Publications and Information (NCEPI)
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Cincinnati, OH 45242

Las publicaciones con las siglas "PB" en el número de documento pueden solicitarse al National Technical Information Service (NTIS), teléfono: 1-800-553-6847. Se cobra un cargo por estos documentos. Los pedidos pueden enviarse por correo a:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161

- Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources, EPA 542-B-95-001. **Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.**
- Physical/Chemical Treatment Technology Resource Guide, EPA 542-B-94-008. **Bibliografía de publicaciones y otras fuentes de información sobre el lavado del suelo, el enjuague del suelo in situ, la extracción con solventes y otras técnicas de tratamiento innovadoras.**
- *Engineering Bulletin, Solvent Extraction*, EPA 540-S-94-503, PB94-190477.
- *EPA Engineering Issue: Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment*, EPA 540-S-93-506, PB94-144250/XAB.
- *WASTECH® Monograph on Solvent/Chemical Extraction*, ISBN #1-883767-05-9. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Thermal Desorption

Technology Innovation Office

Technology Fact Sheet

What is thermal desorption?

Thermal desorption is an innovative treatment technology that treats soils contaminated with hazardous wastes by heating soils to temperatures of 200-1,000°F so that contaminants with low boiling points will vaporize (turn into gas) and, consequently, separate from the soil. (The other soil contaminants, if any, are treated by other methods.) The vaporized contaminants are collected and treated, typically by an air emissions treatment system.

Thermal desorption is a different treatment process than incineration. Thermal desorption uses heat to physically separate the contaminants from the soil. The contaminants then require further treatment. Incineration uses heat to actually destroy the contaminants.

How does thermal desorption work?

Typical thermal desorption systems (Figure 1 on page 2) consist of three components: the pre-treatment and material handling system, the desorption unit, and the post-treatment system

for both the gas (vaporized contaminants) and the solid (remaining soil).

Pretreatment and Material Handling System

Pretreatment of contaminated material involves sifting it to remove large clods and foreign debris. If the contaminated material is very wet or has a high level of contaminant, it may need to be blended with sand or dried to make it a more uniform mass for treatment in the desorption unit.

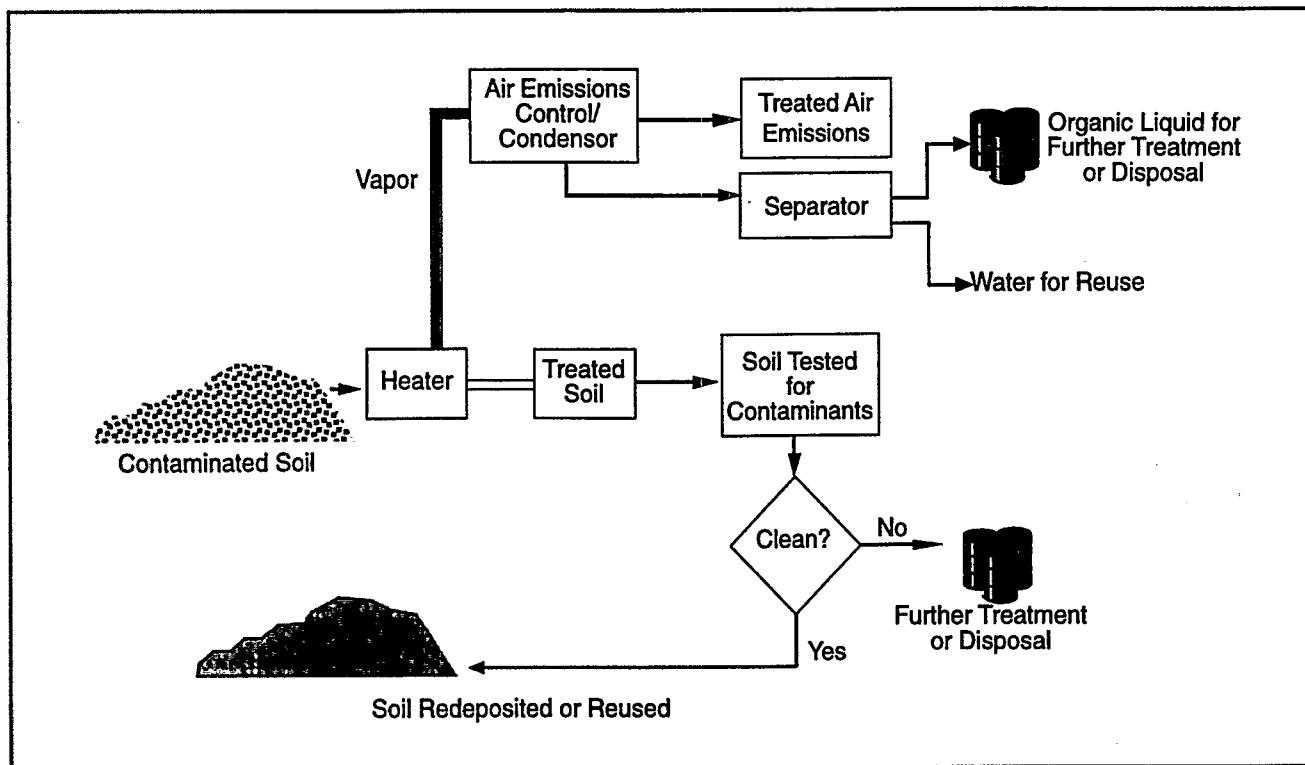
Desorption Unit

The function of the desorption unit is to heat the contaminated soil to a sufficient temperature for a sufficient period to dry it and vaporize the contaminants from the soil. A common design for the desorber unit is a *rotary desorber*, which consists of a rotating cylindrical metal drum. In a *direct-fired rotary desorber*, the material enters the rotating cylinder and is heated by direct contact with a flame or the hot gases coming off a flame. In an *indirect-fired rotary desorber*, the contaminated soil does not come into contact

A Quick Look at Thermal Desorption

- Heats soil at relatively low temperatures to vaporize contaminants and remove them.
- Is most effective at treating volatile organic compounds, semi-volatile organic compounds and other organic contaminants, such as polychlorinated biphenyls (PCBs), and polyaromatic hydrocarbons (PAHs) and pesticides.
- Is useful for separating organic contaminants from refining wastes, coal tar wastes, wood-treatment wastes and paint waste.

Figure 1
The Thermal Desorption Process



with a flame or combustion gases. Instead, the outside of the metal cylinder is heated and the hot metal indirectly heats the soil tumbling inside. As the waste is heated, the contaminants vaporize, and then become part of the gas stream of air and contaminated vapors flowing through the desorber towards the post-treatment system. An *inert*, or non-reactive gas, such as nitrogen, may be added to the gas stream to prevent the vaporized contaminants from catching fire in the desorption unit and to aid in vaporizing and removing the contaminants.

Post-treatment System

"Offgas" from the desorber is typically processed to remove particulates that remained in the gas stream after the desorption step. Vaporized contaminants in the offgas may be burned in an afterburner, collected on activated carbon, or recovered in condensation equipment. Depending on the contaminants and their concentrations, any or all of these methods may be

used. All disposals must meet federal, state, and local standards.

Treated soil from the desorber is tested to measure how well the process removed the target contaminants. The performance of thermal desorption is typically measured by comparing the contaminant levels in treated soils with those of untreated soils. If the treated soil is non-hazardous, it is redeposited on-site or taken elsewhere to be used as backfill. If, however, the soil requires further treatment (for example, the soil contained contaminants that did not respond to this process), it may be treated with another technology or transported off-site for disposal.

Why consider thermal desorption?

Thermal desorption is effective at separating organics from refining wastes, coal tar wastes, waste from wood treatment, and paint wastes. It can separate solvents, pesticides, PCBs, dioxins and fuel oils from contaminated soil. The

equipment available is capable of treating up to 10 tons of contaminated soil per hour. Finally, the lower temperatures require less fuel than other treatment methods.

Will it work at every site?

Thermal desorption is not applicable to most metals, although mercury can be removed by the process. Other metals will either remain in the treated soil, in which case the soil must be retreated, or vaporize, in which case they may complicate the offgas treatment. The presence of metals and their fate must be determined before the soil is processed.

Thermal desorption is not equally efficient at treating all types of soil. If the soil is wet, water will vaporize along with the contaminants. Because of the additional substance (water) being vaporized, more fuel is required to vaporize all of the contaminants in the wet soil. Soils with high silt and clay content are also more difficult to treat with thermal desorption. When heated, silt and clay emit dust, which can disrupt the air emission equipment used to treat the vaporized contaminants. In addition, tightly packed soil often does not permit the heat to

make contact with all of the contaminants. Therefore, it is difficult for them to vaporize. Finally, thermal desorption would not be a good choice for treating contaminants such as heavy metals, since they do not separate easily from the soil, and strong acids, since they can corrode the treatment equipment.

Where is thermal desorption being used?

Thermal desorption has been selected as a treatment method at numerous Superfund sites. For example, thermal desorption was used at the TH Agriculture & Nutrition Company site in Albany, Georgia. Thermal desorption was used at the site to treat 4,300 tons of oil contaminated with pesticides (dieldren, toxaphene, DDT, lindane). The system ran from July to October 1993. Thermal desorption met the cleanup goals, removing over 98% of the pesticides in the treated soil. Table 1 on page 4 lists some additional Superfund sites where thermal desorption has been used or selected for use.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste. *Innovative treatment technologies* are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

Although thermal desorption is widely used, innovative variations are continually being developed. It is still difficult to predict with certainty the time and cost to clean a site using thermal desorption. For these reasons, it retains its "innovative" label as EPA continues to track its performance.

Table 1
Examples of Superfund Sites Using Thermal Desorption (all projects completed)*

Name of Site	Type of Facility	Contaminants
Re-solve, MA	Chemical reclamation	Volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs)
Metaltec/Aerosystems, NJ	Metal manufacturing	VOCs
Reich Farms, NJ	Chemical drum storage/disposal	VOCs, semi-volatile organic compounds (SVOCs)
American Thermostat, NJ	Thermostat manufacturing	VOCs
U.S.A. Letterkenney SE Area, PA	Munitions manufacturing/storage	VOCs
Wamchem, SC	Dye manufacturing	Benzene, toluene, ethylbenzene & xylene (BTEX), VOCs, SVOCs
Jacksonville NAS, FL	Fire training site	Polyaromatic hydrocarbons (PAHs)
Outboard Marine/Waukegan Harbor, IL	Marine products manufacturing	PCBs
Pristine, OH	Industrial waste treatment facility	BTEX, pesticides, herbicides, VOCs
Sand Creek Industrial, CO	Pesticide manufacturing	Pesticides, herbicides

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

* Not all waste types and site conditions are comparable. Each site must be individually investigated and tested. Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

For More Information

The publications listed below can be ordered free of charge by calling NCEPI at 513-489-8190 or faxing your request to 513-489-8695. If NCEPI is out of stock of a document, you may be directed to other sources. You may write to NCEPI at:

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Resources*, EPA 542-B-95-001. A bibliography of EPA publications about innovative treatment technologies.
- *Physical/Chemical Treatment Technology Resource Guide*, September 1994, EPA 542-B-94-008. A listing of publications and other sources of information about thermal desorption and other treatment technologies.
- *Engineering Bulletin, Thermal Desorption*, February 1994, EPA 540-S-94-501.
- *Abstracts of Remediation Case Studies*, March 1995, EPA 542-R-95-001.
- *WASTECH® Monograph on Thermal Desorption*, ISBN #1-883767-06-7. Available for \$49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.

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Guía del ciudadano: La desorción térmica

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué es la desorción térmica?

La desorción térmica es una técnica innovadora para tratar la tierra contaminada con desechos peligrosos calentándola a una temperatura de 90°C a 540°C a fin de que los contaminantes con un punto de ebullición bajo se vaporicen (se conviertan en gases) y, por consiguiente, se separen de la tierra. (Si quedan otros contaminantes, se tratan con otros métodos.) Los contaminantes vaporizados se recogen y se tratan, generalmente con un sistema de tratamiento de emisiones.

La desorción térmica es diferente de la incineración. La desorción térmica usa el calor para separar físicamente los contaminantes de la tierra, que después se someten a un tratamiento ulterior. La incineración usa el calor para destruir los contaminantes.

¿Cómo funciona la desorción térmica?

Los sistemas de desorción térmica típicos (figura 1, página 2) tienen tres componentes: el sistema de tratamiento preliminar y movimiento de materiales, el dispositivo de desorción y el sistema posterior al

tratamiento para gases (contaminantes vaporizados) y sólidos (la tierra que queda).

Sistema de tratamiento preliminar y movimiento de materiales

El tratamiento preliminar de materiales contaminados consiste en pasarlos por una criba para entresacar tirones grandes y materia extraña. Si el material contaminado está muy húmedo o tiene una concentración elevada de contaminantes, tal vez sea necesario mezclarlo con arena o secarlo para que se convierta en una masa más uniforme que pueda tratarse con el equipo de desorción.

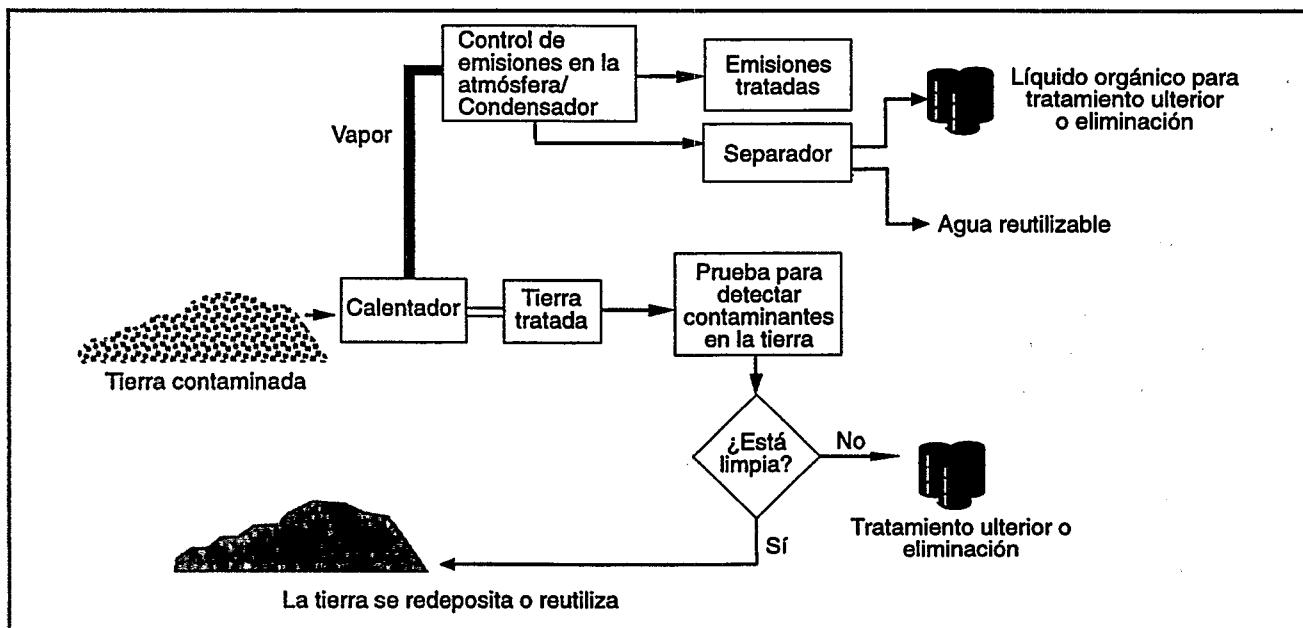
Equipo de desorción

La función del equipo de desorción es calentar la tierra contaminada y mantenerla a una temperatura suficiente durante el período necesario para secarla y vaporizar los contaminantes que contenga. Un tipo común es el *dispositivo de desorción giratorio*, que consiste en un tambor cilíndrico giratorio de metal. En el *dispositivo de resorción giratorio de calentamiento directo*, el material

Perfil de la desorción térmica

- Se calienta la tierra a una temperatura relativamente baja para vaporizar los contaminantes y extraerlos.
- Es sumamente eficaz para el tratamiento de compuestos orgánicos volátiles y semivolátiles, otros contaminantes orgánicos, como bifenilos policlorados, hidrocarburos poliaromáticos y plaguicidas.
- Sirve para separar contaminantes orgánicos de desechos de refinerías, desechos de alquitrán de hulla, desechos del tratamiento de la madera y desechos de pinturas.

Figura 1
El proceso de desorción térmica



entra en el cilindro giratorio y se calienta al entrar en contacto con una llama o con los gases calientes emitidos por una llama. En un *dispositivo de desorción giratorio de calentamiento indirecto*, la tierra contaminada no entra en contacto con una llama o con gases de la combustión, sino que se calienta el exterior del cilindro de metal, y el metal calienta indirectamente la tierra que da vueltas adentro. A medida que los desechos se calientan, los contaminantes se vaporizan y se integran a la corriente gaseosa de aire y vapores contaminados que sale del dispositivo de desorción y se dirige al sistema posterior al tratamiento. Se puede agregar un gas *inerte* (es decir, un gas no reactivo), como nitrógeno, a la corriente de gas para evitar que los contaminantes vaporizados se prendan fuego en el dispositivo de desorción y facilitar la vaporización y remoción de los contaminantes.

Sistema posterior al tratamiento

Los efluentes gaseosos del dispositivo de desorción generalmente son sometidos a un tratamiento para retirar las partículas que queden en la corriente de gas después del procedimiento de desorción. Los contaminantes vaporizados de los efluentes gaseosos se pueden quemar en un quemador auxiliar, recoger

con carbón activado o recuperar en un condensador. Según los contaminantes y su concentración, se puede usar cualquiera de estos métodos o todos ellos. Los métodos de eliminación deben ceñirse a las normas federales, estatales y locales.

La tierra tratada en el dispositivo de desorción es sometida a una prueba para determinar la medida en que se han retirado los contaminantes que se procura extraer con esta técnica. La eficacia de la desorción térmica generalmente se determina comparando la concentración de contaminantes en la tierra tratada con la concentración de contaminantes en tierra sin tratar. Si la tierra tratada no es peligrosa, se vuelve a colocar en su lugar de origen o se lleva a otro sitio para usarla como relleno. Sin embargo, si la tierra necesita tratamiento ulterior (por ejemplo, si contiene contaminantes que no responden a este proceso), se puede tratar con otra técnica o transportar a otro lugar para su eliminación.

¿En qué casos convendría usar la técnica de desorción térmica?

La desorción térmica es eficaz para separar materia orgánica de desechos de refinerías, desechos de alquitrán de hulla, desechos del tratamiento de la

madera y desechos de pinturas. Puede separar solventes, plaguicidas, bifenilos policlorados, dioxinas y fuel-oil de tierra contaminada. El equipo puede tratar hasta 10 toneladas de tierra contaminada por hora. Por último, como trabaja a temperaturas más bajas, consume menos combustible que el equipo utilizado para otros tratamientos.

¿Dará resultado esta técnica en cualquier lugar?

La desorción térmica no se puede aplicar a la mayoría de los metales, aunque con esta técnica se puede extraer mercurio. Los demás metales permanecen en la tierra tratada, en cuyo caso hay que volver a tratarla, o se vaporizan, y entonces pueden complicar el tratamiento de los efluentes gaseosos. Es necesario determinar la presencia de metales y su destino antes de tratar la tierra.

La desorción térmica no es igualmente eficiente en el tratamiento de todos los tipos de suelos. Si la tierra está húmeda, el agua se evaporará junto con los contaminantes. Debido a la sustancia adicional (agua) que se evapora, se necesita más combustible para vaporizar todos los contaminantes de la tierra húmeda. Los suelos con alto contenido de limo y arcilla también son más difíciles de tratar con la desorción

térmica. Cuando el limo y la arcilla se calientan, emiten polvo, que puede perturbar el equipo para emisiones que se usa para tratar los contaminantes vaporizados. Además, si el suelo es muy compacto, el calor a menudo no llega a entrar en contacto con todos los contaminantes, de modo que es difícil que se vaporicen. Por último, la desorción térmica no sería una buena opción para tratar contaminantes tales como metales pesados, que no se separan fácilmente de la tierra, y ácidos fuertes, que pueden corroer el equipo utilizado para el tratamiento.

¿Dónde se está usando la desorción térmica?

Se ha seleccionado la desorción térmica para el tratamiento de varios sitios con recursos del *Superfund*. Por ejemplo, se usó en el predio de TH Agriculture & Nutrition Company, en Albany (Georgia), para tratar 4.300 toneladas de aceite contaminado con plaguicidas (dieldrina, toxafeno, DDT, lindano). El sistema funcionó desde julio hasta octubre de 1993. Con la desorción térmica se alcanzaron las metas de descontaminación: se extrajo más del 98% de los plaguicidas de la tierra tratada. En el cuadro 1 de la página 4 hay una lista de otros sitios para los cuales se ha usado o seleccionado la desorción térmica con recursos del *Superfund*.

¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos. Con técnicas de tratamiento se pueden alterar materiales contaminados, destruyéndolos o modificándolos, a fin de que sean menos peligrosos o dejen de ser peligrosos. Con ese fin se puede reducir la cantidad de material contaminado, recuperar o retirar un componente que confiera al material sus propiedades peligrosas o inmovilizar los desechos. Las *técnicas de tratamiento innovadoras* son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Aunque la desorción térmica está muy difundida, continuamente aparecen variantes innovadoras. Todavía es difícil prever con certeza el tiempo que se tardará en descontaminar un sitio con la técnica de desorción térmica y cuánto costará. Por estas razones, conserva el calificativo de "innovadora" mientras el EPA lleva un registro de su desempeño.

Cuadro 1
Ejemplos de sitios donde se usó la desorción térmica con recursos del *Superfund*
(todas las operaciones han concluido)*

Nombre del sitio	Tipo de instalación	Contaminantes
Re-solve (Massachusetts)	Recuperación de productos químicos	Compuestos orgánicos volátiles, bifenilos policlorados
Metaltec/Aerosystems (Nueva Jersey)	Fabricación de metales	Compuestos orgánicos volátiles
Reich Farms (Nueva Jersey)	Almacenamiento y eliminación de barriles de productos químicos	Compuestos orgánicos volátiles, compuestos orgánicos semivolátiles
American Thermostat (Nueva Jersey)	Fabricación de termostatos	Compuestos orgánicos volátiles
U.S.A. Letterkenney SE Area (Pensilvania)	Fabricación y almacenamiento de municiones	Compuestos orgánicos volátiles
Wamchem (Carolina del Sur)	Fabricación de tinturas	Benceno, tolueno, etilbenceno y xileno, compuestos orgánicos volátiles, compuestos orgánicos semivolátiles
Jacksonville NAS (Florida)	Sitio para entrenamiento de bomberos	Hidrocarburos poliaromáticos
Outboard Marine/ Waukegan Harbor (Illinois)	Fábrica de productos para la navegación	Bifenilos policlorados
Pristine (Ohio)	Estación de tratamiento de desechos industriales	Benceno, tolueno, etilbenceno y xileno, plaguicidas, herbicidas, compuestos orgánicos volátiles
Sand Creek Industrial (Colorado)	Fabricación de plaguicidas	Plaguicidas, herbicidas

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del *Superfund*, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Hay una base de datos con más información sobre los sitios indicados en el *Annual Status Report*. La base de datos se puede recibir gratis por computadora; está en la cartelera electrónica con información sobre operaciones de limpieza del EPA (CLU-IN). Llame a CLU-IN, módem: 301-589-8366. El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discetes. Consulte al NCEPI para más pormenores.

- * No todos los tipos de desechos y no todas las condiciones de los sitios son comparables. Es necesario investigar cada sitio y someterlo a pruebas por separado. Se deben emplear criterios científicos y técnicos para determinar si una técnica es apropiada para un sitio.

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- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, EPA 542-B-95-001. Bibliografía de publicaciones del EPA sobre técnicas de tratamiento innovadoras.
- *Physical/Chemical Treatment Technology Resource Guide*, septiembre de 1994, EPA 542-B-94-008. Bibliografía de publicaciones y otras fuentes de información sobre la desorción térmica y otras técnicas de tratamiento innovadoras.
- *Engineering Bulletin, Thermal Desorption*, febrero de 1994, EPA 540-S-94-501.
- *Abstracts of Remediation Case Studies*, marzo de 1995, EPA 542-R-95-001.
- *WASTECH® Monograph on Thermal Desorption*, ISBN #1-883767-06-7. Puede obtenerse de la Academia Estadounidense de Ingenieros Ambientales, 130 Holiday Court, Annapolis, Maryland 21401; teléfono: 410-266-3311. Cuesta US\$49,95.

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A Citizen's Guide to Treatment Walls

Technology Innovation Office

Technology Fact Sheet

What are treatment walls?

Treatment walls are structures installed underground to treat contaminated ground water found at hazardous waste sites. Treatment walls, also called *passive treatment walls* or *permeable barriers*, are put in place by constructing a giant trench across the flow path of contaminated ground water and filling it with one of a variety of materials (reactive fillings) carefully selected for the ability to clean up specific types of contaminants. As the contaminated ground water passes through the treatment wall, the contaminants are either trapped by the treatment wall or transformed into harmless substances that flow out of the wall (Figure 1).

How do they work?

The reactive filling of a treatment wall is often mixed with sand or some other porous material to make it less dense than the soil around it. This encourages ground water to flow through the wall because it provides the "path of least resistance." At some sites, an underground funnel system is added to direct the contaminated ground water to the wall.

The specific filling chosen for a wall is based on the types of contaminants found at the site. Different fillings do their job through different

chemical processes: *sorption*, *precipitation*, and *degradation*.

Sorption barriers contain fillings that remove contaminants from ground water by physically "grabbing" contaminants out of the ground water and holding them on the barrier surface (Figure 2a). Examples of these adsorbents are *zeolites*—tiny cage-like particles that trap molecules of contaminants inside them—and activated carbon which has a very rough surface that contaminant molecules stick to as they pass.

Precipitation barriers contain fillings that react with contaminants in ground water as they seep through the wall (Figure 2b). The reaction causes the contaminants dissolved in the ground water to change so they are no longer dissolved and "precipitate" out. These "insoluble" products are left trapped in the barrier and clean ground water flows out the other side. For example, lead is a common contaminant at industrial sites where careless recycling of automobile batteries has taken place. The lead-saturated battery acid that seeped into the ground water at these sites is difficult to trap and treat. A precipitation barrier filled with limestone placed across the path of the acidic, lead-contaminated ground water neutralizes the acid. This causes the lead to change to a

A Quick Look at Treatment Walls

- Are passive systems that require no mechanical equipment or energy source.
- Allow the site to be put to productive use while being cleaned up.
- Can be modified to treat different types of contaminants.
- Completely break down some organic contaminants.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to the treatment of hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means.

Innovative treatment technologies are those that have been tested, selected or used for treatment of hazardous waste or contaminated materials but lack well-documented cost and performance data under a variety of operating conditions.

solid form that is trapped in the barrier. Highly toxic chromium (VI), a by-product of metal-plating operations, is treated by precipitation barriers in a similar way. It is changed to immobile chromium (III) which is trapped in the barrier.

Degradation barriers cause reactions that break down or "degrade" the contaminants in the ground water into harmless products (Figure 2c). For example, fillings of iron granules degrade certain volatile organic compounds. Walls also may be filled with a mixture of nutrients and oxygen

sources which stimulate the activity of the microorganisms found in the ground water. Healthy microorganisms are important because they are responsible for the *biodegradation* of contaminants. Biodegradation is the process that naturally occurring microorganisms (yeast, fungi, or bacteria) use to break down, or *degrade*, hazardous substances into less toxic or nontoxic substances. Microorganisms, just like humans, eat and digest organic substances for nutrition and energy. (In chemical terms, "organic" compounds are those that contain carbon and hydrogen atoms.) Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans. The fact sheet entitled *A Citizen's Guide to Bioremediation* describes the process in detail (see page 4).

Much research and testing has been done on the use of iron for the treatment of chlorinated contaminants. The reaction that occurs when contaminants come in contact with iron granules puts to beneficial use the common chemical reaction called *oxidation* that causes iron to rust. As the iron is oxidized, the toxic component of the contaminant (usually a chlorine atom) is removed from the compound. The iron granules are dissolved by the process, but the metal disappears so

Figure 1. Schematic Diagram of a Treatment Wall

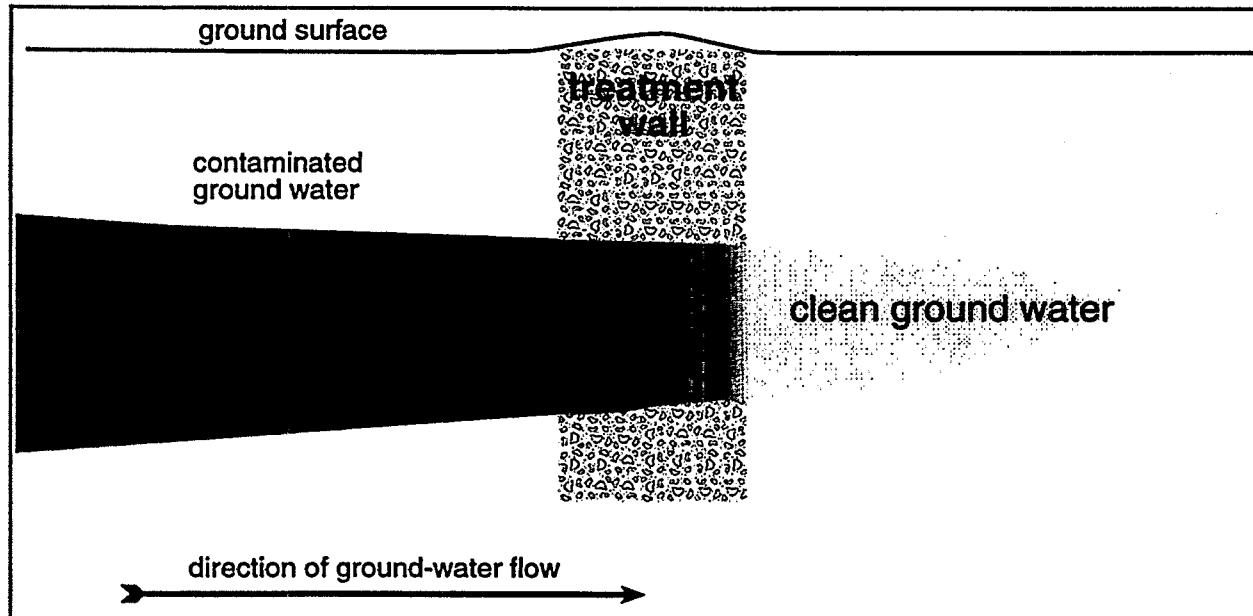
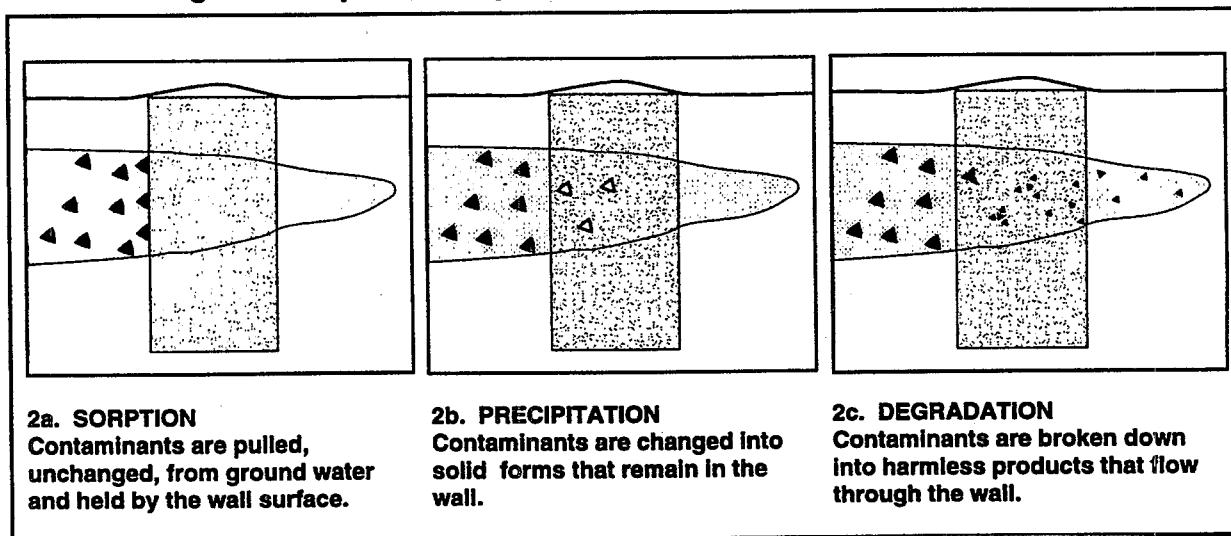


Figure 2. Sorption, Precipitation, and Degradation Treatment Walls



slowly that remediation barriers, engineers predict, will remain effective for many years, even decades. These iron granules are a by-product of manufacturing processes so their use as a barrier wall material has the added benefit of recycling this material.

Iron can be used to degrade many common chlorinated organic compounds such as trichloroethylene (TCE), tetrachloroethylene (PCE), dichloroethene (DCE) and 1,1,1-trichloroethane (TCA). Mixing palladium, another metal, with the iron granules enables the wall to treat contaminants that iron alone cannot treat.

Why use treatment walls?

The major advantage of treatment walls over traditional treatment methods such as pump-and-treat is that they are passive systems that treat the contaminants in place. There is no need to dig up contaminated soil or pump out contaminated water, there are no parts to break, no need for electricity, and, since there is no equipment on the surface, the property can be put to productive use while it is being cleaned up. Engineers estimate at least a 50% cost savings using treatment walls instead of pumping out contaminated ground water.

Will they work at every site?

The ideal site for a treatment wall is one having porous sandy soil, contamination no deeper than

about 50 feet below ground, and a good, solid flow of ground water.

There are an estimated 5,000 Department of Defense, Department of Energy, and Superfund sites contaminated with chlorinated solvents. Probably 10 to 20 percent of these have the right conditions to use treatment walls. Treatment walls also are useful at sites contaminated with metals and radioactive contaminants.

The successful application of a treatment wall requires careful study of the underground environment and an understanding of the contaminant and ground-water flow.

In lab studies, some clogging of wall materials has been observed. So far, clogging has not occurred in the field, but walls have only been in place for a few years.

Where have they been used?

At a former semiconductor manufacturing site in Sunnyvale, California, 220 tons of iron shavings were used to fill a reactive treatment wall that has been breaking down TCE since December 1994. The above-ground equipment that was part of a previously installed pump-and-treat system was removed and the site has been leased to another company that uses it as a parking lot. Some Superfund sites that have chosen treatment walls as a cleanup method are listed in Table 1 on page 4.

Table 1. Some Superfund Sites that Plan to Use Treatment Walls*

Name of Site	Type of Wall/Filling	Contaminants	Site Use
Brown's Battery Breaking Site, PA	Precipitation/Limestone	Lead	Battery recycling & disposal
Tonolli Corporation, PA	Precipitation/Limestone	Lead	Battery recycling & disposal
Somersworth Sanitary Landfill, NH	Degradation/Iron	Organics	Municipal & industrial landfill

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled *Innovative Treatment Technologies: Annual Status Report (7th Ed.)*, EPA 542-R-95-008. Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information (CLU-IN) World Wide Web site (<http://clu-in.com>) or electronic bulletin board (301-589-8366). The CLU-IN help line number is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

*Not all waste types and site conditions are comparable. Each site must be individually investigated and tested. Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.

For More Information

The publications listed below can be ordered free of charge by faxing your request to NCEPI at 513-489-8695. If NCEPI is out of stock of a document, you may be directed to other sources. You may write to NCEPI at:

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- *A Citizen's Guide to Bioremediation*, April 1996, EPA 542-F-96-007.
- "Metal-Enhanced Abiotic Degradation of VOCs," *Ground Water Currents* (newsletter), July 1995, EPA 542-N-95-004.
- "Funnel and Gate System Directs Plume," *Ground Water Currents* (newsletter), June 1993, EPA 542-N-93-006.
- "*In Situ* Degradation of Halogenated Organics by Permeable Reaction Wall," *Ground Water Currents* (newsletter), March 1993, EPA 542-N-93-003.
- *Permeable Barriers Action Team*, April 1996, EPA 542-F-96-010c.
- *In Situ Remediation Technology Status Report: Treatment Walls*, April 1995, EPA 542-K-4-004.
- "Zero-Valent Metals Provide Possible Solution to Groundwater Problems" by Elizabeth K. Wilson in *Chemical and Engineering News*, July 23, 1995, pages 19-22.
- "When Toxics Meet Metal" by Virginia Fairweather in *Civil Engineering*, May 1996, pages 44-48.

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Guía del ciudadano: Muros de tratamiento

Oficina de Innovaciones Tecnológicas

Ficha tecnológica

¿Qué son los muros de tratamiento?

Los muros de tratamiento son estructuras subterráneas para tratar agua subterránea contaminada en vertederos de desechos peligrosos. Para construir muros de tratamiento, llamados también *muros de tratamiento pasivo* o *barreras permeables*, se hace una zanja gigante a través de un curso de agua subterránea contaminada y se rellena con uno de diversos tipos de materiales (rellenos reactivos) seleccionado minuciosamente por su capacidad para eliminar determinados tipos de contaminantes. Cuando el agua subterránea contaminada pasa por el muro de tratamiento, los contaminantes quedan atrapados en el muro o salen transformados en sustancias inocuas (figura 1).

¿Cómo funcionan?

El relleno reactivo del muro de tratamiento con frecuencia se mezcla con arena u otro material poroso para que sea menos denso que el suelo que lo rodea. De esta forma se encauza el agua para que fluya por el muro al ofrecerle "el trayecto de menor resistencia". En algunos lugares se agrega un sistema de embudos subterráneos para dirigir el agua contaminada hacia el muro.

El relleno que se selecciona para un muro depende de los tipos de contaminantes que haya en el lugar. Cada tipo de relleno actúa por medio de procesos químicos diferentes: *sorción*, *precipitación* y *degradación*.

Las **barreras de sorción** contienen rellenos que retiran contaminantes del agua subterránea capturándolos físicamente y reteniéndolos en la superficie de la barrera (figura 2a). Algunos ejemplos de estos adsorbentes son las ceolitas, partículas diminutas con forma de jaula que atrapan moléculas de contaminantes en su interior, y el carbón activado, que tiene una superficie muy áspera a la cual se adhieren los contaminantes al pasar.

Las **barreras de precipitación** contienen rellenos que reaccionan con contaminantes del agua subterránea que pasan por el muro (figura 2b). La reacción produce un cambio en los contaminantes disueltos en el agua subterránea: salen del estado de disolución y se precipitan. Estos productos "insolubles" quedan atrapados en la barrera, y el agua subterránea sale limpia del otro lado. Por ejemplo, el plomo es un contaminante común en sitios industriales donde se han reciclado baterías de automóviles sin las debidas precauciones. El ácido de las baterías saturado de plomo que se filtra por el suelo y llega hasta el agua subterránea de estos sitios es difícil de atrapar y tratar. Una barrera de precipitación rellena con piedra caliza erigida a través del curso de agua subterránea acídica contaminada con plomo neutraliza el ácido; en consecuencia, el plomo pasa a estado sólido y queda atrapado en la barrera. El cromo sumamente tóxico (VI), subproducto de las operaciones de revestimiento metálico, se trata con barreras de precipitación en forma similar y se convierte en cromo inmóvil (III), que queda atrapado en la barrera.

Perfil de los muros de tratamiento

- Son sistemas pasivos que no requieren equipo mecánico ni una fuente de energía.
- Permiten usar el sitio mientras se está limpiando.
- Se pueden modificar para tratar distintos tipos de contaminantes.
- Descomponen por completo algunos contaminantes orgánicos.

¿Qué son las técnicas de tratamiento innovadoras?

Las *técnicas de tratamiento* son procesos que se aplican a desechos peligrosos o materiales contaminados para alterar su estado en forma permanente por medios químicos, biológicos o físicos.

Las *técnicas de tratamiento innovadoras* son técnicas que han sido ensayadas, seleccionadas o utilizadas para el tratamiento de desechos peligrosos o materiales contaminados, aunque todavía no se dispone de datos bien documentados sobre su costo y resultados en diversas condiciones de aplicación.

Las barreras de degradación causan reacciones que descomponen o "degradan" los contaminantes del agua subterránea, convirtiéndolos en productos inocuos (figura 2c). Por ejemplo, el relleno de gránulos de hierro degrada ciertos compuestos orgánicos volátiles. Los muros también pueden llenarse con una mezcla de nutrientes y fuentes de oxígeno que estimulan la actividad de los microorganismos del agua subterránea. Los microorganismos sanos son importantes porque se encargan de la biodegradación de los contaminantes. La biodegradación es el proceso que realizan los microorganismos naturales (levaduras, hongos o

bacterias) para descomponer o degradar sustancias peligrosas en sustancias menos tóxicas o inocuas. Los microorganismos, igual que los seres humanos, comen y digieren sustancias orgánicas para nutrirse y obtener energía. (En términos químicos, compuestos "orgánicos" son los que contienen átomos de carbono e hidrógeno.) Ciertos microorganismos pueden digerir sustancias orgánicas tales como combustibles o solventes, que son peligrosos para los seres humanos. En la ficha tecnológica titulada *Guía del ciudadano: Medidas biocorrectivas* se describe el proceso de biodegradación en forma pormenorizada (véase la página 4).

Se han realizado amplias investigaciones y pruebas con respecto al uso de hierro para el tratamiento de contaminantes clorados. Cuando los contaminantes entran en contacto con los gránulos de hierro se produce la reacción química común de oxidación, por la cual el hierro se oxida, que en este caso se aprovecha con un fin beneficioso. Con la oxidación del hierro, se retira del compuesto el componente tóxico del contaminante (generalmente un átomo de cloro). Los gránulos de hierro se disuelven en este proceso, pero el metal desaparece tan lentamente que, según los cálculos de los ingenieros, las barreras correctivas siguen actuando durante varios años e incluso décadas. Estos gránulos del hierro son un derivado de procesos de fabricación, de modo que su

Figura 1. Diagrama de un muro de tratamiento

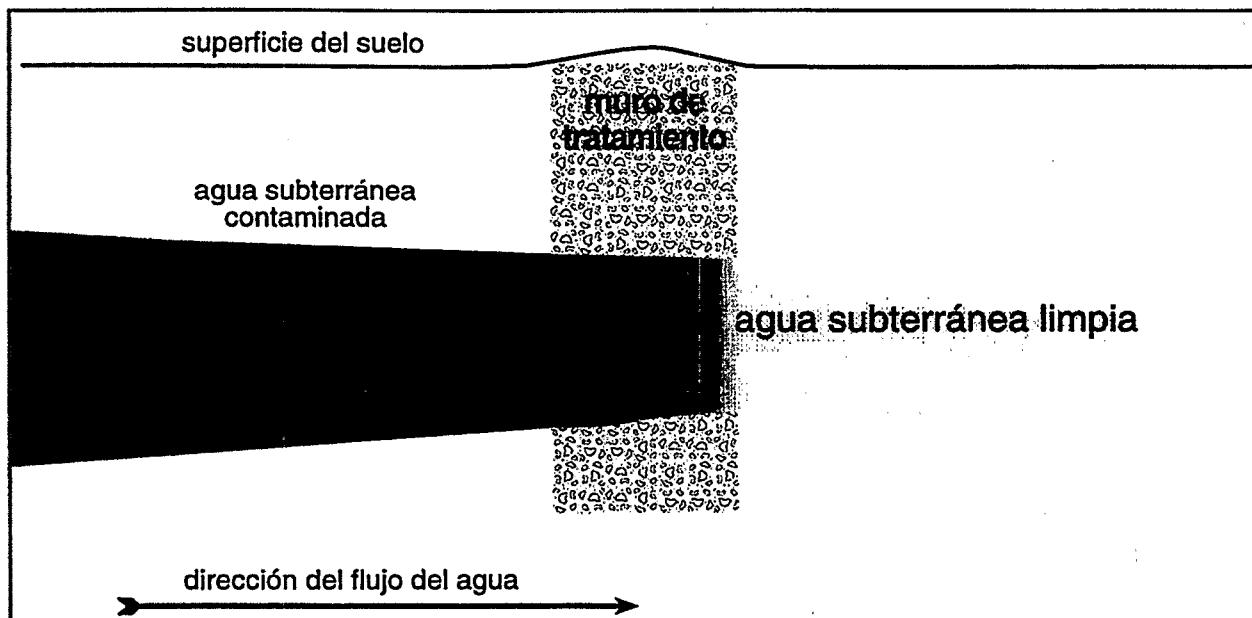
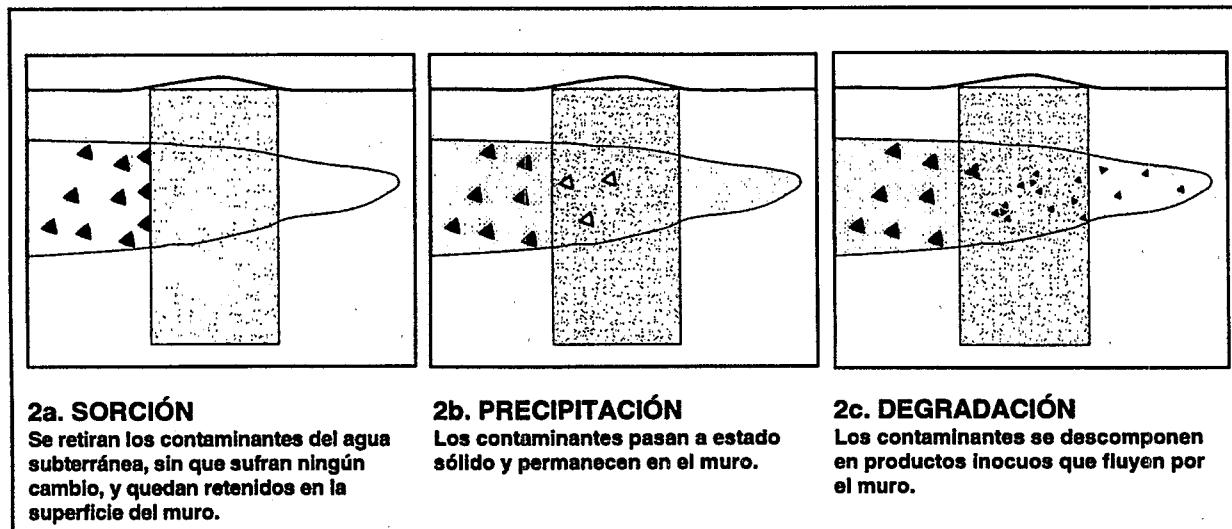


Figura 2. Muros de tratamiento por sorción, precipitación y degradación



uso como material para barreras tiene la ventaja adicional de que permite reciclar este material.

El hierro se puede usar para degradar varios compuestos orgánicos clorados comunes, como tricloroetileno (TCE), tetracloroetileno (PCE), dicloroetano (DCE) y 1,1,1-tricloroetano (TCA). Si se mezcla paladio (otro metal) con los gránulos de hierro, el muro se puede usar para tratar contaminantes que no se pueden tratar con hierro solamente.

¿Por qué conviene usar muros de tratamiento?

La ventaja principal de los muros de tratamiento en comparación con métodos tradicionales tales como el bombeo y tratamiento es que son sistemas pasivos que tratan los contaminantes *in situ*. No es necesario excavar tierra contaminada o bombear agua contaminada, no tienen piezas que puedan averiarse, no se necesita electricidad y, como no hay que instalar ningún aparato en la superficie, se puede usar el lugar mientras se limpia. Los ingenieros calculan que, usando muros de tratamiento en vez de bombear agua contaminada, se puede ahorrar por lo menos el 50% del costo.

¿Dará resultado esta técnica en cualquier lugar?

El sitio ideal para un muro de tratamiento es un lugar con suelo arenoso poroso, contaminado hasta una profundidad de 15 metros como máximo y una corriente de agua subterránea abundante y constante.

Se calcula que hay alrededor de 5.000 sitios del Ministerio de Defensa, el Ministerio de Energía y el *Superfund* contaminados con solventes clorados, de los cuales entre el 10% y el 20% probablemente tengan características apropiadas para el uso de muros de tratamiento. Los muros de tratamiento también son útiles en los lugares contaminados con metales y contaminantes radiactivos.

Para que el muro de tratamiento dé resultado, es necesario realizar un estudio pormenorizado del medio subterráneo y comprender el contaminante y el flujo del agua.

En estudios de laboratorio se han observado casos de atascamiento. Hasta ahora no se ha observado este problema sobre el terreno, pero los muros fueron construidos hace pocos años.

¿Dónde se ha usado esta técnica?

En un lugar de Sunnyvale (California) donde se fabricaban semiconductores se usaron 220 toneladas de viruta de hierro para llenar un muro de tratamiento reactivo que ha estado descomponiendo TCE desde diciembre de 1994. El equipo instalado en la superficie, que formaba parte de un sistema de bombeo y tratamiento instalado anteriormente, fue trasladado, y el lugar ha sido arrendado a una compañía que lo usa como estacionamiento. En el cuadro 1 de la página 4 figuran algunos sitios para los cuales se han seleccionado los muros de tratamiento como método de limpieza con recursos del *Superfund*.

Cuadro 1. Algunos sitios donde se planea usar muros de tratamiento con recursos del Superfund*

Nombre del sitio	Tipo de muro/ Relleno	Contaminantes	Uso del sitio
Brown's Battery Breaking Site (Pennsylvania)	Precipitación/ Piedra caliza	Plomo	Reciclaje y eliminación de baterías
Tonolli Corporation (Pennsylvania)	Precipitación/ Piedra caliza	Plomo	Reciclaje y eliminación de baterías
Somersworth Sanitary Landfill (Nueva Hampshire)	Degradación/ Hierro	Orgánicos	Vertedero municipal e industrial

Si desea una lista de los sitios para los cuales se han usado o seleccionado técnicas de tratamiento innovadoras con recursos del Superfund, diríjase al NCEPI, cuya dirección figura en el recuadro a continuación, y solicite un ejemplar del documento titulado *Innovative Treatment Technologies: Annual Status Report (7th Ed.), EPA 542-R-95-008*. Hay una base de datos con más información sobre los sitios indicados en el Annual Status Report. La base de datos se puede recibir gratis por computadora; está en la World Wide Web, en el sitio del EPA con información sobre operaciones de limpieza (<http://clu-in.com>) o en la cartelera electrónica (301-589-8366). El número de teléfono de CLU-IN para ayuda técnica es 301-589-8368. La base de datos también se puede comprar en discquetes. Consulte al NCEPI para más pormenores.

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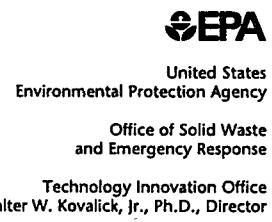
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- "In Situ Degradation of Halogenated Organics by Permeable Reaction Wall", *Ground Water Currents* (boletín), marzo de 1993, EPA 542-N-93-003.
- *Permeable Barriers Action Team*, abril de 1996, EPA 542-F-96-010c.
- *In Situ Remediation Technology Status Report: Treatment Walls*, abril de 1995, EPA 542-K-4-004.
- "Zero-Valent Metals Provide Possible Solution to Groundwater Problems," de Elizabeth K. Wilson, en *Chemical and Engineering News*, 23 de julio de 1995, páginas 19-22.
- "When Toxics Meet Metal," de Virginia Fairweather, en *Civil Engineering*, mayo de 1996, páginas 44-48.

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CLU-IN

CLEAN-UP INFORMATION SYSTEM

World Wide Web Site and Electronic Bulletin Board

Internet Access

WWW site: <http://clu-in.com>
FTP site: <ftp://clu-in.com>
Telnet to BBS: <telnet://clu-in.epa.gov> (or 134.67.99.13)

Modem Access

BBS modem number: 301-589-8366
Modem speed: Up to 28,800 baud
Communications parameters: 8 data bits, 1 stop bit, no parity
Terminal emulation: VT-100 or ANSI

Voice Help Line

Telephone number: (301) 589-8368

The Hazardous Waste Clean-up Information (CLU-IN) World Wide Web Site and Electronic Bulletin Board System (BBS) provide information about innovative treatment technologies to the hazardous waste remediation community. Both the web site and BBS offer a variety of information for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens.

CLU-IN World Wide Web Site

<http://clu-in.com>

- Read about the operation, development, and commercialization of innovative site characterization and remediation technologies and programs such as interagency consortia and public-private partnerships designed to facilitate their use.
- Download recent documents and databases designed to aid those responsible for hazardous waste site remediation.
- Link to Internet sources of information on environmental restoration and technology development.
- Link to the CLU-IN BBS with the click of a button.

CLU-IN Electronic Bulletin Board System (BBS)

(301) 589-8366

- Download the same files and databases offered on the WWW site.
- Communicate with hazardous waste professionals online through the message exchange system.
- Visit Special Interest Group areas moderated by EPA's Office of Underground Storage Tanks (UST), Association of State and Territorial Solid Waste Management Officials (ASTSWMO), and others.

Types of Information on CLU-IN

Some of the information available on the CLU-IN system is summarized below.

- **Encyclopedia of Innovative Technologies.** Descriptions, applications, limitations, cost and performance data, and schematic diagrams for numerous remediation and characterization technologies. Includes links to additional information on CLU-IN and other sites (WWW site only).
- **Technology Innovation News Survey—Biweekly Update.** A summary of news items related to research, commercialization, and applications of hazardous waste remediation and site characterization technologies.
- **Tech Trends.** A newsletter providing descriptions and performance data for innovative cleanup technologies that have been applied in the field.
- **Ground Water Currents.** A newsletter of information on the development and demonstration of innovative ground-water remediation techniques. Includes reports on technologies, new regulations that impact ground-water remediation, discussions of issues such as DNAPLs, and information on conferences and publications.
- **Bioremediation in the Field.** An information update on applying bioremediation to site cleanup. Descriptions of treatability studies underway; bioremediation projects at CERCLA, RCRA, UST, and TSCA sites; and technical support and publications offered by EPA.
- **Underground Tank Technology Update.** A newsletter funded by EPA and published by the University of Wisconsin-Madison providing

information about the cleanup of ground water and soil contaminated by leaking underground storage tanks.

- **Innovative Treatment Technologies (ITT) Annual Status Report.** A report on applications of innovative treatment technologies for remedial and removal actions. The companion ITT Database provides additional detailed site-specific information.
- **Full text documents** on technologies such as bioremediation, soil vapor extraction, surfactant and cosolvent flushing, fracturing, treatment walls, thermal enhancement technologies, electrokinetics, and other ground-water and physical/chemical treatment technologies.

Databases Available for Downloading

- Vendor Information System for Innovative Treatment Technologies (VISITT)
- Innovative Treatment Technologies (ITT) Annual Status Report Database
- Vendor Field Analytical and Characterization Technologies System (Vendor FACTS)
- Bioremediation in the Field Search System (BFSS)

Other Regularly Updated Information

- Announcements of opportunities for contracting with the federal government on projects involving hazardous waste remediation.
- Full text of recent *Federal Register* notices related to hazardous waste and ground-water issues.
- Calendar of conferences, workshops, and technology demonstrations.
- Announcements of new EPA publications.

Getting Help

A voice help line is available from 9:00am to 5:00pm Eastern Time to help you connect to and use the CLU-IN WWW site and BBS. The help line phone number is (301) 589-8368.

The CLU-IN WWW is available to anyone with Internet access. The CLU-IN BBS is available free of charge 365 days a year, 24 hours a day, to anyone with a modem and communications software. Choose your own password and complete a short online registration during your first visit to gain immediate access. Detailed assistance for BBS commands is available through online help. To get help with any BBS prompt, type H. You will get a list of choices for responses to that prompt.

Remediation Technologies Screening Matrix

	Development Status	Availability	Residuals Produced (excludes Train and Gas treatment)	Contaminants Treated								Overall Cost Intensive							
				VOCs	SVOCs	Fuels	Inorganic	Explosives	System Reliability/ Maintainability	Cleanup Time									
NOTE: Specific site and contaminant characteristics may limit the applicability and effectiveness of any of the technologies and treatments listed below. This matrix is optimistic in nature and should always be used in conjunction with the referenced text sections, which contain additional information that can be useful in identifying potentially applicable technologies.																			
SOIL, SEDIMENT, AND SLUDGE																			
3.1 In Situ Biological Treatment																			
4.1 Biodegradation	Full	█	None	No	█	█	△	█	△	█	█	O&M							
4.2 Bioventing	Full	█	None	No	█	█	△	█	█	█	█	Neither							
4.3 White Rot Fungus	Pilot	△	None	No	△	△	△	△	█	△	█	O&M							
3.2 In Situ Physical/Chemical Treatment																			
4.4 Pneumatic Fracturing (enhancement)	Pilot	△	None	Yes	●	●	●	●	█	NA	█	Neither							
4.5 Soil Flushing	Pilot	█	Liquid	No	█	█	█	█	█	△	█	O&M							
4.6 Soil Vapor Extraction (In Situ)	Full	█	Liquid	No	█	█	█	█	█	█	█	O&M							
4.7 Solidification/Stabilization	Full	█	Solid	No	△	△	█	█	█	█	█	CAP							
3.3 In Situ Thermal Treatment																			
4.8 Thermally Enhanced SVE	Full	●	Liquid	No	●	●	●	●	●	●	●	Both							
4.9 Vitrification	Pilot	△	Liquid	No	●	●	●	●	●	●	●	Both							
3.4 Ex Situ Biological Treatment (assuming excavation)																			
4.10 Composting	Full	█	None	No	█	█	△	█	█	█	█	Neither							
4.11 Controlled Solid Phase Bio. Treatment	Full	█	None	No	█	█	△	█	█	█	█	Neither							
4.12 Landfarming	Full	█	None	No	█	█	△	█	█	△	█	Neither							
4.13 Slurry Phase Bio. Treatment	Full	●	None	No	█	█	△	█	█	█	█	Both							
3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)																			
4.14 Chemical Reduction/Oxidation	Full	█	Solid	Yes	●	●	●	█	█	█	●	Neither							
4.15 Dehalogenation (BCD)	Full	△	Vapor	No	●	●	△	△	△	—	—	—							
4.16 Dehalogenation (Glycolate)	Full	●	Liquid	No	●	●	△	△	△	△	△	Both							
4.17 Soil Washing	Full	●	Solid, Liquid	Yes	●	●	█	█	█	█	█	Both							
4.18 Soil Vapor Extraction (Ex Situ)	Full	█	Liquid	No	█	█	●	△	△	—	—	Neither							
4.19 Solidification/Stabilization	Full	█	Solid	No	△	●	△	█	█	█	█	CAP							
4.20 Solvent Extraction (chemical extraction)	Full	●	Liquid	Yes	●	●	●	█	█	△	△	Both							
3.6 Ex Situ Thermal Treatment (assuming excavation)																			
4.21 High Temperature Thermal Desorption	Full	█	Liquid	Yes	●	●	●	●	●	●	●	Both							
4.22 Hot Gas Decontamination	Pilot	●	None	No	△	△	△	△	△	—	—	Both							
4.23 Incineration	Full	█	Liquid,Solid	No	●	●	█	△	△	●	●	Both							
4.24 Low Temperature Thermal Desorption	Full	█	Liquid	Yes	█	●	△	△	△	—	—	Both							
4.25 Open Burn/Open Detonation	Full	█	Solid	No	△	△	△	△	△	—	—	Both							
4.26 Pyrolysis	Full	△	Liquid,Solid	No	●	●	●	△	—	—	—	Both							
4.27 Vitrification	Full	●	Liquid	No	●	●	●	█	█	●	●	Both							
3.7 Other Treatment																			
4.28 Excavation, Retrieval, and Off-Site Disposal	NA	█	NA	No	●	●	●	●	●	—	—	Neither							
4.29 Natural Attenuation	NA	█	None	No	█	█	█	△	△	—	—	Neither							
Rating Codes (See Table 3-1)																			
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">█ Better</td> <td style="width: 15%;">● Inadequate Information</td> <td style="width: 15%;">— Not Applicable</td> <td style="width: 15%;">△ Worse</td> <td style="width: 15%;">—</td> <td style="width: 15%;">—</td> <td style="width: 15%;">—</td> </tr> </table>													█ Better	● Inadequate Information	— Not Applicable	△ Worse	—	—	—
█ Better	● Inadequate Information	— Not Applicable	△ Worse	—	—	—													

Remediation Technologies Screening Matrix (Continued)

NOTE: Specific site and contaminant characteristics may limit the applicability and effectiveness of any of the technologies and treatments listed below. This matrix is optimistic in nature and should always be used in conjunction with the referenced text sections, which contain additional information that can be useful in identifying potentially applicable technologies.

	Development Status	Availability	Residuals Produced	Treatment Excludes Off-gas treatment	VOCs	SVOCs	Fuels	Inorganic	Explosives	Contaminants Treated	System Reliability/Maintainability	Cleanup Time	Overall Cost	O&M or Capital Intensive
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GROUNDWATER, SURFACE WATER, AND LEACHATE

3.8 In Situ Biological Treatment														
4.30 Co-metabolic Treatment	Pilot	△	None	No	█	█	●	△	●	△	●	●	O&M	
4.31 Nitrate Enhancement	Pilot	△	None	No	█	█	●	△	●	●	●	█	Neither	
4.32 Oxygen Enhancement with Air Sparging	Full	█	None	No	█	█	●	△	●	●	●	●	Neither	
4.33 Oxygen Enhancement with H ₂ O ₂	Full	█	None	No	█	█	●	△	●	●	●	●	O&M	
3.9 In Situ Physical/Chemical Treatment														
4.34 Air Sparging	Full	█	Vapor	Yes	█	△	●	△	●	●	█	█	Neither	
4.35 Directional Wells (enhancement)	Full	△	NA	Yes	●	●	●	●	●	●	●	●	Neither	
4.36 Dual Phase Extraction	Full	█	Liquid,Vapor	Yes	█	△	●	△	●	●	●	●	O&M	
4.37 Free Product Recovery	Full	█	Liquid	No	△	█	●	△	●	●	●	●	Neither	
4.38 Hot Water or Steam Flushing/Stripping	Pilot	●	Liquid,Vapor	Yes	●	█	●	△	●	●	●	●	CAP	
4.39 Hydrofracturing (enhancement)	Pilot	I	None	Yes	●	●	●	●	●	●	●	●	Neither	
4.40 Passive Treatment Walls	Pilot	△	Solid	No	█	●	●	●	●	●	●	●	CAP	
4.41 Slurry Walls (containment only)	Full	█	NA	NA	●	●	●	●	●	●	●	●	CAP	
4.42 Vacuum Vapor Extraction	Pilot	△	Liquid,Vapor	No	█	█	I	△	●	●	●	●	CAP	
3.10 Ex Situ Biological Treatment (assuming pumping)														
4.43 Bioreactors	Full	█	Solid	No	█	█	●	△	●	●	NA	█	CAP	
3.11 Ex Situ Physical/Chemical Treatment (assuming pumping)														
4.44 Air Stripping	Full	█	Liquid,Vapor	No	█	●	●	△	●	●	NA	█	O&M	
4.45 Filtration	Full	█	Solid	Yes	△	△	△	●	●	●	█	█	Neither	
4.46 Ion Exchange	Full	█	Solid	Yes	△	△	△	●	●	●	●	●	Neither	
4.47 Liquid Phase Carbon Adsorption	Full	█	Solid	No	█	●	●	●	●	●	NA	△	O&M	
4.48 Precipitation	Full	█	Solid	Yes	△	△	△	●	●	●	●	●	Neither	
4.49 UV Oxidation	Full	█	None	No	█	█	█	△	●	●	NA	●	Both	
3.12 Other Treatment														
4.50 Natural Attenuation	NA	█	None	No	█	█	●	△	●	●	█	█	Neither	
3.13 AIR EMISSIONS/OFF-GAS TREATMENT														
4.51 Biofiltration	Full	●	None		█	●	●	△	●	●	NA	●	Neither	
4.52 High Energy Corona	Pilot	△	None	NA	█	●	●	△	●	●	NA	●	I	
4.53 Membrane Separation	Pilot	△	None		█	●	●	△	●	●	NA	●	I	
4.54 Oxidation	Full	█	None		█	█	●	△	●	●	NA	█	Neither	
4.55 Vapor Phase Carbon Adsorption	Full	█	Solid		█	█	●	●	●	●	NA	█	Neither	

Rating Codes (See Table 3-1)

- █ Better
- Average
- △ Worse

I Inadequate Information

NA Not Applicable

Source: Remediation Technologies Screening Matrix and Reference Guide (PB95-104782)

Selecting Innovative Cleanup Technologies: EPA Resources

EPA offers many informational resources to aid in identifying and screening innovative technologies for waste site remediation.

Daniel M. Powell,
U.S. Environmental
Protection Agency,
Technology Innovation Office

The scope of the contaminated site cleanup problem in the United States indicates the need for more effective, less costly remediation technologies. However, the menu of routinely selected treatment options is minimal.

Existing technologies do not provide all of the answers to this dilemma. Although proven remedies are indeed effective in certain settings, they are limited by a number of factors. For example, incinerators can be very costly and difficult to site. In addition, many of the technologies used to date do not address some of the more complex problems faced at contaminated sites (such as mixed radioactive and hazardous wastes, or dense nonaqueous phase liquids [DNAPLs] in groundwater).

Although innovative solutions are being selected for a growing number of cleanup actions, several barriers hinder their routine use. The availability of adequate performance and cost data on such technologies is one of the greatest obstacles. These data are lacking mainly because only 14 of the 263 Superfund source control projects for which innovative remedies were selected have reached completion, the stage where performance and cost information become available.

This lack of information on the full-scale field use of innovative technologies is problematic for several reasons. First, it decreases the willingness of regulators and the public to accept new remedies for site cleanup. And, it discourages site managers from selecting innovative technologies for use at their sites, since data are not avail-

able to compare these technologies to more proven remedies.

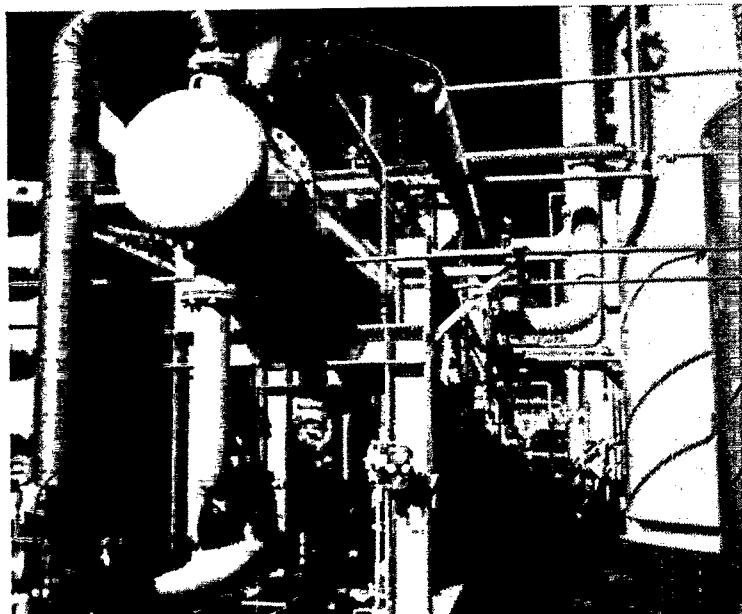
The U.S. Environmental Protection Agency (EPA) encourages the use of innovative technologies, and by improving the availability of information to decision-makers at hazardous waste sites, the Agency hopes that they will be considered more often. Indeed, EPA offers a number of resources to site managers as they move through the decision-making process that leads to remedy selection.

This article describes the steps involved in researching the technology alternatives and the information available from EPA at each of these steps. It is not intended to be an authoritative guide to the remedy selection process. Rather, it can serve as a roadmap to help site managers navigate through the growing amount of information available on innovative treatment technologies. This roadmap should help managers categorize data available to identify and narrow the alternatives applicable to particular sites. Each publication description includes an EPA identification number, and the sidebar on p. 35 contains ordering instructions.

Steps in the remedy selection process

The following discussion of publications and databases is organized as a model reflecting the phases through which the hazardous waste site decision-maker progresses. In the initial remedy scoping phase, a site manager must identify and conduct a preliminary review of cleanup

alternatives and locate the data available on each of them. This step involves both a screening of potential technologies and a search of the existing literature describing those technologies. In the feasibility study stage, the site manager must then review the information gathered and analyze its applicability to the particular site. Finally, the site manager must determine the site-specific applicability of the technologies identified in the first two phases, and, ultimately, develop a decision document (e.g., a Superfund Record of Decision [ROD]) justifying the selection of the most appropriate alternative for that site.



■ Soil and groundwater remediation occurs simultaneously in this integrated vapor extraction/steam vacuum stripping system. Photo courtesy AWD Technologies.

In addition to these steps, some activities are interwoven throughout the selection process. The site manager should network among other professionals as well as identify and weigh the policy considerations involved in selecting remedies at hazardous waste sites. And, although treatability studies can occur in the latter stages of the technology selection process to help determine the applicability of a particular treatment process to a site-specific problem, EPA encourages site managers to conduct them as early in the process as possible.

The stages outlined above provide a

convenient framework for describing information resources available from EPA to analyze innovative cleanup options. These resources are developed primarily by two offices within EPA — the Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD). Within these organizations, the Technology Innovation Office, the Office of Emergency and Remedial Response, the Office of Solid Waste, the Office of Underground Storage Tanks, and EPA Laboratories provide numerous resources to assist site decision-makers with remedy selection. The rest of this article highlights the resources related to innovative technologies, focusing primarily on technologies available for source control and the treatment of contaminated soils.

Technology screening

The first step in the remedy selection process involves a general screening of the technologies available for dealing with the particular problem at the site. As a tool to scope innovative options, EPA, in conjunction with the U.S. Air Force, has developed the *Remediation Technologies Screening Matrix and Reference Guide* (EPA/542/B-93/005).

The first part of this document is a general screening matrix that compares technologies for soils, sediments and sludge, groundwater, and air emission/off-gas treatment according to a variety of parameters. These parameters include: the development status of the technology; contaminant groups treated; whether the technology is capital or operation-and-maintenance (O&M) intensive; whether it is used as part of a treatment train; residuals produced; whether it addresses toxicity, mobility, or volume; and long-term effectiveness and permanence. In addition, the matrix rates each technology (better, adequate, worse, inadequate information available, or not applicable) according to overall cost, time to complete cleanup, system reliability and maintenance requirements, awareness of the remediation consulting community, regulatory and permitting acceptability, and community acceptability.

The second portion of this document,

the reference guide, provides additional information to increase the usability of the matrix. It describes the basis of the ratings, gives more detailed information on the strengths and weaknesses of each technology, and includes citations to published information on each technology type.

In general, the *Screening Matrix and Reference Guide* is intended as a general reference to be used in the initial screening. It should not be used as the sole basis for remedy selection. A review of more detailed references along with an analysis of individual site conditions should follow this initial screening process.

To provide a fuller understanding of the menu of innovative technologies, EPA has developed several general technology survey reports giving extensive information on innovative technologies. One such resource is *Innovative Treatment Technologies: Overview and Guide of Information Sources* (EPA/540/9-91/002; PB92-179001). This is a compilation of information on treatment technologies available for use in the Superfund program.

The *Overview* includes sections on incineration, thermal desorption, soil washing, solvent extraction, dechlorination, bioremediation, vacuum extraction, *in situ* vitrification, and groundwater treatment. Each section contains: brief descriptions of the processes employed by the technology; summaries of its status, applications, strengths, and weaknesses; and, where available, facts on waste site characteristics that may affect performance. The document also lists reference materials and provides contacts within EPA, state agencies, and the contractor community who have experience with issues related to these technologies. Although the *Overview* is relevant at this initial screening stage, it

Ordering the publications

All of the documents discussed in this article are readily accessible to hazardous waste professionals, both public and private.

Many of the references are available, in limited quantities, free of charge. Documents with EPA... numbers can be obtained from the National Center for Environmental Publications and Information (NCEPI). OSWER Directives are available from the Superfund Document Center.

When supplies are exhausted, a PB... number is assigned, and the publication must be ordered, for a fee, from the National Technical Information Service (NTIS).

To order, simply provide your request, including publication numbers, to one of the following organizations:

NTIS:

U.S. Dept. of Commerce
National Technical Information Service
Springfield, VA 22161
703/487-4650; Fax: 321-8547

NCEPI:

U.S. EPA
National Center for Environmental Publications and Information (NCEPI)
26 W. Martin Luther King Dr.
Cincinnati, OH 45268
Fax Orders: 513/891-6685
No telephone orders accepted

Superfund Document Center:

U.S. EPA
Superfund Document Center
401 M St., SW, DS-245
Washington, DC 20460
Attn: Superfund Directives
202/260-9760

The Technology Innovation Office has also developed an electronic resource useful in screening innovative technologies and identifying technology vendors. The *Vendor Information System for Innovative Treatment Technologies* (VISITT) contains current information on the availability, performance, and cost of innovative treatments to remediate contaminated hazardous waste sites. The searchable database allows the user to find information on commercially available treatment processes based on a number of criteria, including contaminants, waste type, and waste source. It includes technologies at all levels of development — bench-, pilot-, and full-scale. This system enables vendors to notify the user communities of the availability of their technologies, and it enables site managers to determine what technologies may be available to treat the problems encountered at their sites.

VISITT Version 2.0 is now available. It profiles 231 technologies offered by 141 companies, 65% of which are available commercially at full-scale. Of the 231 technologies, 28 treat groundwater *in situ*, 164 treat soil, 77 treat sludge, 66 treat natural sediments, 32 treat solids, and 10 are off-gas treatments; 149 of the technologies treat volatile organics, 146 treat semi-volatile organics, 46 treat metals, and 28 treat other inorganics.

The VISITT system is distributed free of charge through EPA's National Center for Environmental Information (NCEPI) [see sidebar]. Information on the contents of the system along with details for ordering it can be found in the *VISITT Bulletin* (EPA/542/N-93/004).

EPA's Risk Reduction Engineering Laboratory has developed a series of *Engineering Bulletins* summarizing the latest information on specific treatment and remediation processes. These bulletins provide site managers with an understanding of the data and site characteristics necessary to evaluate (at the technology scoping level) the potential applicability of a

should remain useful throughout the remedy selection process.

For site managers facing problems related to underground storage tanks (USTs) for petroleum products, *Technologies and Options for UST Corrective Actions: Overview of Current Use* (EPA/542/R-92/010; PB93-145589) summarizes treatment technologies used in state UST corrective-action programs. It also includes descriptions and operating parameters for a number of innovative technologies pertinent to UST-related contaminants. Finally, it gives examples of some of the state requirements that may affect the use of the technologies.

technology to their particular problem.

As the program gathers new information on the technologies, addenda will be added to ensure that the documents remain up-to-date. The bulletins related to innovative treatment technologies published to date are listed in Table 1. In addition, EPA plans to publish two new bulletins, including one on *in situ* biodegradation.

Literature review

After the initial screening of available technologies, the next step in the selection process is a review of available literature on the potentially applicable options. Various resources are readily accessible, both searchable electronic media as well as the more generally used print media.

Electronic media. The foremost bibliographic database on hazardous waste site treatment technologies offered by EPA is the *Alternative Treatment Technology Information Center (ATTIC)*. It contains information on biological, chemical, and physical treatment processes, solidification and stabilization, and thermal treatment technologies. The *ATTIC* system provides users with on-line access to several databases as well as an electronic bulletin board, a hot line (which allows searches for those without computer capabilities), and a repository of documents related to alternative and innovative treatment technologies.

The primary component of *ATTIC* is the *ATTIC* database, a searchable, bibliographic database providing abstracts on over 2,000 references. The on-line system also provides access to a treatability database, a message center, and a comprehensive calendar of technology-related events.

There is no charge for the use of *ATTIC* and it is available 24 hours a day, seven days a week. The on-line number for the *ATTIC* system is 703/908-2138, and the system operator/hotline number is 703/908-2137. The settings for on-line access to *ATTIC* are 8 data bits, no parity, and 1 stop bit.

A publication developed to facilitate

access to the large body of information related to innovative treatment technologies is *Accessing Federal Data Bases For Contaminated Site Clean-Up Technologies, Third Edition* (EPA/542/B-93/008 or PB94-144540). It contains a series of 23 profiles describing databases, expert systems, and electronic bulletin boards maintained by federal agencies. The listed systems contain information on innovative technologies or on completed demonstration projects. The publication explains the type of information each system contains, and notes the accessibility of the systems (restricted vs. open), hardware and software specifications, and agency contacts.

In addition to federally sponsored systems, various commercial databases and software can assist cleanup professionals in locating bibliographic information. To improve awareness of the available literature in the field of hazardous waste cleanup technologies, EPA has prepared a *Literature Survey of Innovative Technologies for Hazardous Waste Site Remediation: 1987-1991* (EPA/542/B-92/004). Compiled based on a search of com-

mercial databases (including CA Search, Compendex Plus, Energy Science and Technology Database, the National Technical Information Service (NTIS) Database, and Pollution Abstracts), this document is an extensive listing of technical literature related to innovative technologies, organized by technology type.

[CEP's annual *Software Directory* is another source of information on available software. — Editor]

Print resources. EPA also provides printed materials useful in identifying technology references. *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation* (EPA/542/B-93/010) is a bibliography of EPA reports describing treatment technologies for hazardous waste sites. Published semi-annually, this brochure provides titles, document numbers, and ordering information for technology documents. The bibliography also includes details on EPA information systems relevant to site cleanup technologies.

A broader look at the reports and publications available from the federal government as a whole is provided by

Table 1. EPA Engineering Bulletins on specific remediation technologies.

Subject	Document Number
Solvent Extraction Treatment	EPA/540/2-90/013
Mobile/Transportable Incineration Treatment	EPA/540/2-90/014
Chemical Dehalogenation: Alkali	
Polyethylene Glycol (PEG) Treatment	EPA/540/2-90/015
Slurry Biodegradation	EPA/540/2-90/016
Soil Washing Treatment	EPA/540/2-90/017
In Situ Steam Extraction	EPA/540/2-91/005
In Situ Soil Vapor Extraction	EPA/540/2-91/006
Thermal Desorption Treatment	EPA/540/2-91/009
In Situ Soil Flushing	EPA/540/2-91/021
Chemical Oxidation Treatment	EPA/540/2-91/025
Supercritical Water Oxidation	EPA/540/S-92/006
Rotating Biological Contactors	EPA/540/S-92/007
Technology Preselection Data Requirements	EPA/540/S-92/009
Pyrolysis Treatment	EPA/540/S-92/010
Selection of Control Technologies for	
Remediation of Lead Battery Recycling Sites	EPA/540/S-92/011
Solidification/Stabilization of	
Organics and Inorganics	EPA/540/S-92/015

Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, Third Edition (EPA/542/B-93/007 or PB94-144557). This 42-page bibliography references reports describing federal research, evaluation, and demonstration of innovative treatment processes for hazardous waste sites. Over 400 reports are referenced and categorized by subject area, with listings for general survey reports as well as technology-specific topic groupings. The bibliography also provides document numbers and ordering information.

Another aid in the literature screening stage is the *Compendium of Superfund Program Publications* (EPA/540/8-91/014). Much more general and comprehensive than the bibliographies, this publication is the most complete source of information provided by EPA on Superfund documents, including fact sheets, directives, publications, and computer materials. The compendium also includes detailed information on how to order Superfund publications, most of which are available through the NTIS for a fee.

Due to the high level of interest in bioremediation, the Technology Innovation Office has developed the *Bioremediation Resource Guide* (EPA/542/B-93/004) to aid decision-makers in reviewing the applicability of bioremediation. This document provides access information on electronic resources and hot lines, cites relevant federal regulations, and abstracts pertinent print resources such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Particularly handy is a detailed "bioremediation resource matrix," which compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how users may obtain the listed publications.

Finally, EPA conducts annual symposia to provide information useful in the literature screening phase of the remedy selection process. The *Forum*

Table 2. Available abstracts from *Forums on Innovative Hazardous Waste Treatment Technologies: Domestic and International* conferences.

1st Forum, Atlanta, GA	EPA/540/2-89/055, PB90-268509
2nd Forum, Philadelphia, PA	EPA/540/2-90/009, PB91-145649
3rd Forum, Dallas, TX	EPA/540/2-91/016, PB92-233881
4th Forum, San Francisco, CA	EPA/540/R-92/081
5th Forum, Chicago, IL	Not Yet Assigned

on Innovative Hazardous Waste Treatment Technologies: Domestic and International is a national conference where hazardous waste professionals can exchange solutions to hazardous waste problems. The last forum, held in San Francisco, November 17-19, 1992, was attended by over 1,000 representatives from the U.S. and 25 foreign countries. Attendees heard 42 technical presentations describing domestic and international technologies for the treatment of waste, sludges, and contaminated soils at hazardous waste sites, focusing on physical/chemical, biological, thermal, and stabilization techniques. Abstracts and papers from this, as well as the first three forums, are available from EPA. Publication numbers for the abstracts are shown in Table 2. The next forum is being held this month (May 3-5 in Chicago), and abstracts from that conference will be available shortly.

Narrowing the options

The next step is the information review and analysis phase. By this point, the site manager has identified information on available alternatives, and can now begin to review the technical publications for more specific information on the options deemed relevant to the particular contamination problem at the site.

EPA has developed a number of resources that contain detailed information on the application of innovative treatment technologies. They can serve as a basis to determine whether alternatives identified in the previous stages warrant further consideration.

Two publications provide brief synopses of innovative technologies that

are in federal demonstration programs. First, the EPA Superfund Innovative Technology Evaluation (SITE) Program publishes an annual compendium of abstracts describing the innovative technologies or processes it has accepted into the SITE program. This publication, entitled *The Superfund Innovative Technology Evaluation Program: Technology Profiles, Sixth Edition* (EPA/540/R-93/526), contains profiles of 156 demonstration, emerging, and monitoring and measurement technologies currently being evaluated. Each profile provides an abstracted description of the technology, a discussion of its applicability to various wastes and media, an update on its development or demonstration status, demonstration results (if available), and contacts (for both the developer and at EPA).

EPA also publishes a compendium of federal demonstration and evaluation projects entitled *Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition* (EPA/542/B-93/009 or PB94-144555). Similar in format to the SITE Technology Profiles, this publication is a compilation of 112 abstracts describing demonstrations of innovative technologies conducted by federal agencies. Of the 112 projects, 32 are classified as bioremediation, 9 as chemical treatment, 17 as thermal treatment, 14 as vapor extraction, 16 as soil washing, and 24 as "other physical treatment." In addition, an appendix contains information on 14 demonstration projects involving incineration and solidification/stabilization. The abstracts profile both completed projects and planned demonstrations that

are nearing implementation. Each profile includes the name and telephone number of a contact for the project.

The SITE Technology Profiles and the Federal Synopses provide brief abstracts on each technology. The full results of each specific project completed under the SITE Demonstration Program are incorporated in two documents, the *Technology Evaluation Report* and the *Applications Analysis Report*.

The *Technology Evaluation Report* is a comprehensive summary of the results of the demonstration. It gives a detailed review of the performance of the technology, as well as the advantages, risks, and costs for a given application. This report focuses on the needs of the site manager who is responsible for evaluating the applicability of the technology in relation to a specific site or waste situation.

The *Applications Analysis Report* (which will become the *Innovative Technology Evaluation Report* within the next year) is intended for use by decision-makers responsible for the selection and implementation of a remedy. It aids site managers in deciding whether the documented technology is viable for further consideration to clean up a specific site. In addition to providing an evaluation of the performance of the technology at the demonstration site, this report incorporates data from other projects to give an indication of the broader applicability of the tested technology. Since waste characteristic differences from site to site may affect a technology's success, it is necessary to examine data available from other field applications. In addition, EPA evaluates the applicability of each technology to sites and wastes other than those tested and studies the technology's likely costs in those situations, and the results from these analyses are included as well. Table 3 shows the *Applications Analysis Reports* now available.

An effort that should be particularly helpful in a detailed review of technologies is the WASTECH project. WASTECH is a multiorganizational

Table 3. Completed "Applications Analysis Reports."

Technology Type	Vendor	Report Number
Biological Technologies		
Biotreatment of Groundwater	Biotrol	EPA/540/A5-91/001 PB91-227983
Physical/Chemical Technologies		
Basic Sludge Extractive		
Treatment (BASIC)	Resources Conservation Co.	EPA/540/AR-92/079
Carver-Greenfield Separation Process	Dahydro-Tech	EPA/540/AR-92/002
Chemical Fixation/ Stabilization	Chamfix Technologies, Inc.	EPA/540/A5-89/011
Chemical Oxidation Treatment	Perox-Pure	EPA/540/AR-93/501
In Situ Stabilization	IWT/Geocon	EPA/540/A5-89/004
In Situ Steam/Hot Air Stripping	Toxic Treatments (USA)	EPA/540/A5-90/008
Integrated Vapor Extraction/Steam		
Vacuum Stripping	AWD Technologies, Inc.	EPA/540/A5-91/002
Membrane Filtration	SBP Technologies	EPA/540/AR-92/014
Membrane Microfiltration	DuPont/Oberlin	EPA/540/A5-90/007
Mobile Volume Reduction Unit	U.S. EPA	EPA/540/AR-93/508
Pneumatic Fracturing and		
Hot Gas Injection	Accutech	EPA/540/AR-93/509
Soil Recycling Treatment Train	Toronto Harbour Commissioners	EPA/540/A5-93/517
Soil Washing	Biotrol	PB92-115245
Solidification	Hazzcon	EPA/540/A5-89/001
Solidification	Solidiftech, Inc.	EPA/540/A5-89/005
Solidification/Stabilization of	Silicate Technology Corporation	EPA/540/AR-92/010 PB93-172348
Organics/inorganics		EPA/540/AR-91/002
Solvent Extraction	CF Systems, Corp.	EPA/540/A5-89/012
UV-Ozone Treatment for Liquids	Ultrox International	EPA/540/A5-89/003
Vacuum Extraction	Terra Vac	PB91-119744
		EPA/540/AR-93/506
Wastewater Treatment System	POWWER	
Thermal Technologies		
Oxygen Enhanced Incineration	American Combustion	EPA/540/A5-89/008 PB90-258427
Cyclone Furnace Vitrification	Babcock and Wilcox	EPA/540/AR-92/017 PB93-122315
Flame Reactor	Horsehead Resource Development	EPA/540/A5-91/005 PB93-184178
Plasma Centrifugal Furnace	Natech	EPA/540/A5-91/007
Low Temperature Thermal	Roy P. Weston, Inc.	EPA/540/AR-92/019
Treatment (LTT)	Shirco	EPA/540/A5-89/010
Infrared Incineration		

initiative (including AIChE's Environmental Div.) being coordinated by the American Academy of Environmental Engineers (AAEE) through a cooperative agreement with EPA's Technology Innovation Office. WASTECH is developing a series of eight engineering monographs on innovative cleanup technologies. The monographs are written by experts in each technology field and are exten-

sively peer-reviewed by government, academic, and professional organizations involved in site cleanup and technology development. Each monograph includes a comprehensive description of the technology or process, a description of suitable applications, an evaluation of the technology based on "a synthesis of available information and informed judgments," a description of the limitations of the process, and a

prognosis of other processes or elements of processes that require further research before considering full-scale application.

The first two monographs, on thermal desorption and soil washing/soil flushing, were completed in late 1993 and are available from AAEE (130 Holiday Court, Suite 100, Annapolis, MD, 21401, 410/266-3311). The remaining six (on stabilization/solidification, vacuum/vapor extraction, thermal destruction, chemical treatment, solvent/chemical extraction, and bioremediation) are in progress. The completed set should be available by late summer or early fall.

Networking

As indicated earlier, the process of networking is not a one-time activity. Instead, networking should take place throughout the selection process. Networking involves communicating with other hazardous waste professionals to learn of their experiences and to tap their expertise. Cleanup decisions have already been made at many sites, and the experiences of those site managers can provide valuable lessons relevant to future remedy selection decisions. To facilitate networking, EPA offers several mechanisms.

The first mechanism consists of technology newsletters, which provide regular forums to publicize ongoing technology applications. EPA publishes three such newsletters on a quarterly basis.

The *Tech Trends* newsletter is self-described as "an applied journal for Superfund removals and remedial actions and RCRA [Resource Conservation and Recovery Act] corrective actions." Among the issues addressed by *Tech Trends* are new technologies, innovative uses of existing technologies, overcoming bureaucratic obstacles to the use of innovative technologies, and the applicability of innovative technologies used in the Superfund program to the RCRA corrective action and closure programs. The most recent issue is

February 1994 (EPA/542/N-94/001). *Bioremediation in the Field* is described as "an information update on applying bioremediation to site cleanup." It features articles on a number of topics, including results of projects at sites supported through EPA's Bioremediation Field Initiative, developments from laboratory and field tests, information on upcoming conferences and seminars, and a listing of relevant bioremediation publications available from EPA or NTIS. It also includes an up-to-date tracking table of sites where bioremediation projects have been completed, are in operation or design, or are being considered for use. The table contains site names, points of contact, contaminants and media treated at each project, project status, clean-up levels, and the specific treatment option chosen for each. This table can provide site managers with a starting point for further information on the applicability of bioremediation to additional sites. The table in the last issue of *Bioremediation in the Field* (March 1994, EPA/540/N-94/500) listed 148 bioremediation sites.

Another newsletter with a specific focus is *Ground Water Currents*, which focuses on issues affecting the development and use of innovative groundwater treatment technologies. Along with articles on field applications of such technologies, *Ground Water Currents* also provides information on groundwater research and regulatory issues affecting the development and application of technologies. The February 1994 issue (EPA/542/N-94/002) is the most recent.

An electronic bulletin board system, the *Cleanup Information (CLU-IN)* bulletin board, allows more timely, day-to-day communications among the clean-up community. *CLU-IN*'s features allow users to exchange messages (either with individual users or to large audiences), exchange computer files and databases, read bulletins on-line, or access several databases on-line. *CLU-IN* also includes a number of special interest group areas (or sub-bulletin boards) on groundwater cleanup, treatability studies, and training.

CLU-IN is available 24 hours a day, seven days a week, and there is no charge to use it. The on-line number for *CLU-IN* is 301/589-8366, and the telecommunications parameters must be set at 8 data bits, no parity, and 1 stop bit. *CLU-IN* also offers a help line staffed by the system operator at 301/589-8368, as well as several source documents, including an introductory flyer (*Exchanging Information on CLU-IN*, EPA/542/F-93/001), a users' guide (*Cleanup Information Bulletin Board System User's Guide*, EPA/542/B-93/002), and a one-hour, self-guided lesson for beginners (*A Guided Tour of CLU-IN*, EPA/542/B-93/003).

Several publications described earlier may also be useful for networking. Both the *Semi-Annual Status Report* and the SITE program's *Tech Profiles* provide contact names for the technology projects that they list. These contacts can provide valuable information on particular technologies. Also, *Accessing Federal Data Bases* lists other electronic systems available from other federal agencies that have communication capabilities.

Site-specific application

Technical assistance. After the options have been researched, a determination must be made as to the site-specific applicability of a particular technology. Several additional resources are available to provide support at this point in the selection process. *Technical Support Services for Superfund Site Remediation and RCRA Corrective Action* (EPA/540/8-91/091) is a directory of services within EPA to assist EPA project managers in solving specific technical problems. Also included are listings of salient publications and information on relevant automated information systems. Although many of the help lines are for EPA personnel only, a number of the resources listed are accessible to outside parties.

Another aid in identifying potential sources of assistance is *Innovative Hazardous Waste Treatment Technologies: A Developer's Guide to Support Services* (EPA/540/2-91/012). The primary purpose of this

publication is to provide technology developers with a listing of resources available to them as they seek to advance their technologies from the proof-of-concept stage to commercialization. The booklet includes information on regulatory requirements applicable to the development of new technologies, sources of grant funding and technical assistance, and the identification of incubator, testing and evaluation, and university-affiliated research facilities that provide a host of development and evaluation services. Some of these services may also be useful to site managers interested in specific technologies.

Treatability studies guidance. The resources discussed thus far can aid a site manager in determining the applicability of a particular technology to site-specific contamination. However, of fundamental importance to remedy selection is the treatability testing process. Treatability studies provide a much clearer indication of whether a technology or treatment process is truly applicable to a specific contamination problem at a site.

To assist site managers in conducting treatability studies, EPA has developed a number of guidance documents that address both general and technology-specific issues. Tables 4 and 5 outline the available documents and fact sheets on treatability testing.

The goal: remedy selection

The resources described so far are intended to lead the hazardous waste professional up to the point of selecting a remedy at an individual site. EPA also provides support at the actual selection point.

Although the benefits of innovative technologies are often cited, site managers have little written guidance to support their decisions in selecting innovative technologies. In fact, some of the regulatory and administrative requirements may impede the use of innovative technologies. Furthermore, the fear of failure for unsuccessful applications of new processes has

Title	Document Number
Analysis of Treatability Data for Soil and Debris: Evaluation of Land Ban Impact on Use of Superfund Treatment Technologies	OSWER Directive 9380.3-04; PB90-269478
Conducting Treatability Studies Under RCRA: Quick Reference Fact Sheet	OSWER Directive 9380.3-09FS; PB92-983501
Guide for Conducting Treatability Studies Under CERCLA — Final	EPA/540/R-92/071A; PB92-126787
Inventory of Treatability Study Vendors: Draft Interim Final	EPA/540/R-90/003a
Regional Guide: Issuing Site-Specific Treatability Variances for Contaminated Soils and Debris for Land Disposal Restrictions (LDRs) — Quick Reference Fact Sheet	OSWER Directive 9380.3-08FS; PB92-983284
The Remedial Investigation Site: Characterization and Treatability Studies	OSWER Directive 9385.3-01FS2 (Fact Sheet); PB90-274408
Treatability Studies Under CERCLA: An Overview, 12/89	OSWER Directive 9380.3-02FS (Fact Sheet); PB90-273970

Table 5. Treatability studies — technology-specific guidance.

Title	Document Number
Aerobic Biodegradation Remedy Selection: Interim Guidance	EPA/540/R-91/013A; PB92-109065
— Quick Reference Fact Sheet	EPA/540/R-91/013B; PB92-109073
Biodegradation Remedy Selection	EPA/540/R-93/519A
Chemical Dehalogenation: Interim Guidance	EPA/540/R-92/013A; PB92-169044
— Quick Reference Fact Sheet	EPA/540/R-92/013B; PB92-169275
Soil Vapor Extraction: Interim Guidance	EPA/540/R-91/019A; PB92-227271
— Quick Reference Fact Sheet	EPA/540/R-91/019B; PB92-231281
Soil Washing: Interim Guidance	EPA/540/R-91/020A; PB92-170570
— Quick Reference Fact Sheet	EPA/540/R-91/020B; PB92-231281
Solvent Extraction	EPA/540/R-92/016A; PB92-239581

also served to create an atmosphere that discouraged the selection of such technologies.

In the summer of 1991, OSWER recognized these shortcomings and issued *Furthering the Use of*

Innovative Treatment Technologies in OSWER Programs, also known as Directive 9380.0-17 (available in fact-sheet format, OSWER Directive 9380.0-17FS) to emphasize the commitment of EPA senior man-

agement to the selection of innovative technologies. This Directive targeted both EPA site managers seeking support for their decisions to select innovative technologies and responsible parties needing a tool to negotiate the use of these technologies with reluctant EPA project managers. The Directive formally emphasizes OSWER's commitment to the use of innovative technologies, and indicates that efforts to further their application are viewed by senior management as a benefit that should be considered in remedy selection decision-making.

The Directive contains a number of initiatives in areas such as: funding for innovative projects; contracting issues; budgetary prioritization; treatability testing; use of innovative

technologies in emergency response actions; testing at federal facilities; enforcement issues; use of innovative technologies in other OSWER programs (UST and RCRA corrective actions); and greater cooperation with private parties through the mechanisms available under the Federal Technology Transfer Act.

Reluctance on the part of management and regulators represents only one hurdle that site managers must clear in selecting innovative technologies at their sites. The public's lack of understanding and fear of being treated as "guinea pigs" represent another barrier.

To assist site managers in addressing the needs of surrounding communities to understand innovative technologies, EPA has prepared a series of *Citizen's Guides to*

Understanding Innovative Treatment Technologies. They are written in predominantly nontechnical language and are available in both English and Spanish. Eight of the *Citizen's Guides* contain information on specific treatment technologies, one provides an overview of innovative treatment technologies, and another highlights success stories about locations where innovative treatment technologies have been applied. Table 6 is a listing of the available *Citizen's Guides*. **CEP**

To receive a free copy of this article, send in the Reader Inquiry Card in this issue with the No. 117 circled.

Table 6. *Citizen's Guides* to understanding innovative treatment technologies.

<i>A Citizen's Guide to...</i>	Document Number
Innovative Treatment Technologies for Contaminated Soils, Sludges, Sediments, and Debris	EPA/542/F-92/001 (English) EPA/542/F-92/014 (Spanish)
How Innovative Treatment Technologies Are Being Successfully Applied at Superfund Sites	EPA/542/F-92/002 (English) EPA/542/F-92/015 (Spanish)
Soil Washing	EPA/542/F-92/003 (English) EPA/542/F-92/016 (Spanish)
Solvent Extraction	EPA/542/F-92/004 (English) EPA/542/F-92/017 (Spanish)
Glycolate Dehalogenation	EPA/542/F-92/005 (English) EPA/542/F-92/018 (Spanish)
Thermal Desorption	EPA/542/F-92/006 (English) EPA/542/F-92/019 (Spanish)
In Situ Soil Flushing	EPA/542/F-92/007 (English) EPA/542/F-92/020 (Spanish)
Bioventing	EPA/542/F-92/008 (English) EPA/542/F-92/021 (Spanish)
Using Indigenous and Exogenous Microorganisms in Bioremediation	EPA/542/F-92/009 (English) EPA/542/F-92/022 (Spanish)
Air Sparging	EPA/542/F-92/010 (English) EPA/542/F-92/023 (Spanish)

Further Reading

U.S. EPA, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends*, Publication No. EPA/542/R-92/012, PB93-140762 (1992).

U.S. EPA, *Innovative Treatment Technologies: Annual Status Report, Fifth Edition*, Publication No. EPA/542/R-93/003 (Sept. 1993).

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**Documents Available from the
US EPA National Risk Management Research Laboratory
Superfund Technology Demonstration Division
General Publications**

- SITE Program: Annual Report to Congress 1994 (EPA/540/R-95/522)
- SITE Profiles, Ninth Edition (EPA/540/R-97/502)
- Survey of Materials Handling Technologies Used at Hazardous Waste Sites (EPA/540/2-91/010)
- Interim Status Report U.S. and German bilateral Agreement on Remediation of Hazardous Waste Sites (EPA/540/R-94/500)

Demonstration Project Results

Accutech Remedial Systems, Inc.--Pneumatic Fracturing Extraction and Hot Gas Injection, Phase 1

- Technology Evaluation (EPA/540/R-93/509)
PB93-216596
- Technology Demo. Summary (EPA/540/SR-93/509)³
- Demonstration Bulletin (EPA/540/MR-93/509)³
- Applications Analysis (EPA/540/AR-93/509)³
PB94-117439

Advanced Remediation Mixing, Inc. (formerly Chemfix)-Chemical Fixation/Stabilization

- Technology Evaluation Vol. 1
(EPA/540/5-89/011a)³ PB91-127696
- Technology Evaluation Vol. 11
(EPA/540/5-89/011b)³ PB90-274127
- Applications Analysis (EPA/540/A5-89/011)
- Technology Demo. Summary (EPA/540/S5-89/011)³
- Demonstration Bulletin (EPA/540/M5-89/011)³

American Combustion, Inc.-Oxygen Enhanced Incineration

- Technology Evaluation (EPA/540/5-89/008)
- Applications Analysis (EPA/540/A5-89/008)
- Technology Demo. Summary (EPA/540/S5-89/008)³
- Demonstration Bulletin (EPA/540/M5-89/008)³

AWD Technologies, Inc.- Integrated Vapor Extraction and Steam Vacuum Stripping

- Applications Analysis (EPA/540/A5-91/002)
PB92-218379
- Demonstration Bulletin (EPA/540/M5-91/002)³

Babcock & Wilcox Co-Cyclone Furnace Vitrification

- Technology Evaluation Vol. 1 (EPA/540/R-92/017A)³
PB92-222215
- Technology Evaluation Vol. 11 (EPA/540/R-92/017B)³
PB92-222223
- Applications Analysis (EPA/540/AR-92/017)
PB93-122315
- Technology Demo. Summary (EPA/540/SR-92/017)³
- Demonstration Bulletin (EPA/540/MR-92/011)

Bergman USA-Soil and Sediment Washing System

- Demonstration Bulletin (EPA/540/MR-92/075)
- Applications Analysis (EPA/540/AR-92/075)

Biogenesis Enterprises, Inc.-Soil and Sediment Washing Processes

- Demonstration Bulletin (EPA/540/MR-93/510)
- Innovative Technology Evaluation Report
(EPA/540/R-93/510)
- SITE Technology Capsule (EPA/540/SR-93/510)³

Bio-Rem, Inc. - Augmented In-Situ Subsurface Bioremedial Process

- Demonstration Bulletin (EPA/540/MR-93/527)

BioTrol - Biological Aqueous Treatment System

- Technology Evaluation (EPA/540/5-91/001)³
PB92-110048
- Applications Analysis (EPA/540/A5-91/001)
PB91-227983
- Technology Demo. Summary (EPA/540/S5-91/001)
- Demonstration Bulletin (EPA/540/M5-91/001)

¹Order documents free of charge by calling EPA's Center for Environmental Research Information (CERI) at 513-569-7562 or Fax 513-569-8695.

²Documents with a PB number are out of stock and must be ordered by that number at cost from:

National Technical Information Service
5285 Port Royal Road
Springfield VA 22161

Telephone 703-487-4650

³Out of stock

Demonstration Project Results (Continued)

- Soil Washing System

- Technology Evaluation Vol. 1
(EPA/540/5-91/003a)³ PB92-115310
- Technology Evaluation Vol. 11 Part A
(EPA/540/5-91/003b)³ PB92-115328
- Technology Evaluation Vol. 11 Part B
(EPA/540/5-91/003c)³ PB92-115336
- Applications Analysis (EPA/540/A5-91/003)
- Technology Demo. Summary (EPA/540/S5-91/003)
- Demonstration Bulletin (EPA/540/M5-91/003)

Brice Environmental Services Corporation-Bescorp Soil Washing System Battery Enterprises Site

- Demonstration Bulletin (EPA/540/MR-93/503)
- Applications Analysis (EPA/540/A5-93/503)

Brown and Root Environmental-Subsurface Volatilization and Ventilation System

- Demonstration Bulletin (EPA/540/MR-94/529)
- Capsule (EPA/540/R-94/529a)
- Innovative Tech. Eval. Report (EPA/540/R-94/529)

Canonic Environmental Services Corporation-Low Temperature Thermal Aeration (LTTA)

- Demonstration Bulletin (EPA/540/MR-93/504)
- Applications Analysis (EPA/540/AR-93/504)

CeTech Resources, Inc., formerly Chemfix Technologies, Inc. - Chemical Fixation/Stabilization

- Technology Evaluation Vol. 1
(EPA/540/5-89/011a) PB91-127696
- Technology Evaluation Vol. 11
(EPA/540/5-89/011b) PB90-274127
- Applications Analysis (EPA/540/A5-89/011)
- Technology Demo. Summary (EPA/540/S5-89/011)³
PB91-921373
- Demonstration Bulletin (EPA/540/M5-89/011)³

CF Systems Corporation-Liquified Gas Solvent Extraction

- Technology Evaluation Vol. 1 (EPA/540/5-90/002)
- Technology Evaluation Vol. 11
(EPA/540/5-90/002a)³ PB90-186503
- Applications Analysis (EPA/540/A5-90/002)
- Technology Demo. Summary (EPA/540/S5-90/002)

Chemical Waste Management, Inc.-X-TRAX Thermal Desorption System

- Demonstration Bulletin (EPA/540/MR-93/502)

Clean Berkshires, Inc. (Now Maxymillian Technologies)

- Thermal Desorption System

- Demonstration Bulletin (EPA/540/MR-94/507)
- Capsule (EPA/540/R-94/507a)³

Dehydro-Tech Corporation-Carver-Greenfield Process

- Technology Evaluation (EPA/540/R-92/002)³
PB92-217462
- Applications Analysis (EPA/540/AR-92/002)
- Technology Demo. Summary (EPA/540/SR-92/002)
- Demonstration Bulletin (EPA/540/MR-92/002)

Dupont/Oberlin-Membrane Microfiltration System

- Technology Evaluation (EPA/540/5-90/007)³
PB92-153410
- Applications Analysis (EPA/540/A5-90/007)
- Technology Demo. Summary (EPA/540/S5-90/007)
- Demonstration Bulletin (EPA/540/M5-90/007)

Dynaphore, Inc.- Forager Sponge Technology

- Demonstration Bulletin (EPA/540/MR-94/522)
- Capsule (EPA/540/R-94/522a)
- Innovative Tech. Eval. Rept. (EPA/540/R-94/522)

ECOVA Corporation - Bioslurry Reactor [Pilot-Scale Demonstration of Slurry-Phase Biological Reactor for Creosote-Contaminated Wastewater]

- Technology Evaluation Vol. 1
(EPA/540/5-91/009)³ PB93-205532
- Applications Analysis (EPA/540/A5-91/009)
- Technology Demo. Summary (EPA/540/S5-91/009)
- Demonstration Bulletin (EPA/540/M5-91/009)

ELI Eco Logic International, Inc.

- GasPhase Chemical Reduction
 - Demonstration Bulletin (EPA/540/MR-93/522)
 - Technology Evaluation Vol. 1
(EPA/540/R-93/522a)³ PB95-100251
 - Technology Evaluation Appendices
(EPA/540/R-93/522b)³ PB95-100251
 - Applications Analysis (EPA/540/AR-93/522)
 - Technology Demo. Summary (EPA/540/SR-93/522)
-
- Thermal Desorption Unit
 - Demonstration Bulletin (EPA/540/MR94/504)
 - Applications Analysis (EPA/540/AR-94/504)

Environmental Technologies, Inc.-Metal-Enhanced Abiotic Degradation Technology

- Demonstration Bulletin (EPA/540/MR95/510)

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Demonstration Project Results (Continued)

EPOC Water, Inc. - Microfiltration Technology

- Demonstration Bulletin (EPA/540/MR93/513)
- Applications Analysis (EPA/540/AR-93/513)

Filter Flow Technology, Inc. - Colloid Polishing Filter Method

- Demonstration Bulletin (EPA/540/MR95/501)
- Capsule (EPA/540/R-94/501a)
PB95-122792
- Innovative Tech. Eval. Rept. (EPA/540/R-94/501)
PB95-122792

Geo-Con, Inc.-In-Situ Solidification and Stabilization Process

- Technology Evaluation Vol. 1 (EPA/540/5-89/004a)
- Technology Evaluation Appendices
(EPA/540/R-93/522b)³ PB95-100251
- Technology Evaluation Vol. 11
(EPA/540/5-89/004b)³ PB89-194179
- Technology Evaluation Vol. 111
(EPA/540/5-89/004c)³ PB90-269069
- Technology Evaluation Vol. IV
(EPA/540/5-89/004d)³ PB90-269077
- Applications Analysis (EPA/540/A5-89/004)
- Technology Demo. Summary (EPA/540/S5-89/004)
- Technology Demo. Summary, Update Report
(EPA/540/S5-89/004a)
- Demonstration Bulletin (EPA/540/M5-89/004)³

Geosafe Corporation - In-Situ Vitrification

- Demonstration Bulletin (EPA/540/MR94/520)
- Capsule (EPA/540/R-94/520a)³
PB95-177101
- Innovative Tech. Eval. Rept. (EPA/540/R-94/520)

GIS/Solutions, Inc. - GIS/KEY Environmental Data Management System

- Demonstration Bulletin (EPA/540/MR94/505)
- Capsule (EPA/540/SR-94/505)
- Innovative Tech. Eval. Rept. (EPA/540/R-94/505)
PB95-138319

Gruppa Italimpresse (developed by Shirco Infrared Systems, Inc.) - Infrared Incineration

- Technology Evaluation -Peake Oil
(EPA/540/5-88/002a)
- Technology Evaluation Report - Peake Oil Vol. 11
(EPA/540/5-88/002b) PB89-116024
- Technology Evaluation - Rose Township
(EPA/540/5-89/007a) PB89-125991
- Technology Evaluation- Rose Township Vol. 11
(EPA/540/5-89/007b) PB89-167910

- Applications Analysis (EPA/540/A5-89/010)
PB89-233423
- Technology Demo Summary(EPA/540/S5-89/007)³
- Demonstration Bulletin (EPA/540/M5-88/002)³

Hazcon, Inc. (now Funderburk and Assoc.) - Solidification Process

- Technology Evaluation Vol. 1 (EPA/540/5-89/001a)
PB89-158810³
- Technology Evaluation Vol. 11 (EPA/540/5-89)001b)
PB89-158828³
- Applications Analysis (EPA/540/A5-89/001)
- Technology Demo Summary (EPA/540/S5-89/001)³
- Demonstration Bulletin (EPA/540/M5-89/001)³

Horsehead Resource Development Co., Inc. - Flame Reactor

- Technology Evaluation Vol. 1
(EPA/540/5-91/005) PB92-205855
- Applications Analysis (EPA/540/A5-91/005)
- Technology Demo Summary (EPA/540/S5-91/005)
- Demonstration Bulletin (EPA/540/M5-91/005)

Hrubetz Environmental Services, Inc. - HRUBOUT Process

- Demonstration Bulletin (EPA/540/MR-93/524)

Huges Environmental Systems, Inc. - Steam Enhanced Recovery Process

- Demonstration Bulletin (EPA/540/MR94/510)
- Capsule (EPA/540R-94/510a)
- Innovative Tech. Eval. Rept. (EPA/540/R-94/510)

IT Research Institute (Brown and Root Environmental, Inc.) - Radio Frequency Heating

- Demonstration Bulletin (EPA/540/MR94/527)
- Capsule (EPA/540/R-94/527a)
- Innovative Tech. Eval. Rept. (EPA/540/R-94/527)

Magnum Water Technology - CAV-OX Ultraviolet Oxidation Process

- Demonstration Bulletin (EPA/540/MR-93/520)
- Applications Analysis (EPA/540/AR-93/520)
PB94-189438
- Technology Evaluation Rep. (EPA/540/R-93/520)³
PB95-166161
- Technology Demo Summary (EPA/540/SR-93/520)

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Demonstration Project Results (Continued)

New York State Multi-Vendor Bioremediation:

- ENSR Consulting & Engineering/Larson Engineers
- Ex-Situ Biovault
 - Demonstration Bulletin (EPA/540/MR-95/524)
- R.E. Wright Environmental Inc. - In-Situ Bioremediation System
 - Demonstration Bulletin (EPA/540/MR-95/525)
- SBP Technologies, Inc. And Env. Laboratories, Inc. Vacuum-Vaporized Well (UVB) System
 - Demonstration Bulletin (EPA/540/MR-96/506)

North American Technologies Group, Inc. - SFC Oleofiltration System

- Demonstration Bulletin (EPA/540/MR-94/525)
- Capsule (EPA/540/R-94/525a)³
PB95-167227
- Innovative Tech. Eval. Rept. (EPA/540/R-94/525)

Ogden Environmental Services, Inc. (now General Atomics) - Ogden Circulating Bed Combustor

- Demonstration Bulletin (EPA/540/MR-92/001)
- Technology Evaluation Rep. (EPA/540/MR-92/001)

Peroxidation Systems, Inc. (now Vulcan) - Perox-Pure™ Chemical Oxidation

- Demonstration Bulletin (EPA/540/MR-93/501)
- Applications Analysis (EPA/540/AR-93/501)
- Technology Evaluation Rep. (EPA/540/R-93/501)
PB93-213528
- Technology Demo Summary (EPA/540/SR-93/501)

Resources Conservation Company - The Basic Extractive Sludge Treatment (B.E.S.T.) - Solvent Extraction

- Demonstration Bulletin (EPA/540/MR-92/079)
- Applications Analysis (EPA/540/AR-92/079)
- Technology Evaluation -Vol. 1
(EPA/540/R-92/079a) PB93-227122
- Technology Evaluation Vol. 11, Part 1
(EPA/540/R-92/079b)³ PB93-227130
- Technology Evaluation Vol. 11, Part 2
(EPA/540/R-92/079c)³ PB93-227148
- Technology Evaluation Vol. 11, Part 3
(EPA/540/R-92/079d)³ PB93-227155
- Technology Demo Summary (EPA/540/SR-92/079)

Ritech, Inc. - Plasma Centrifugal Furnace (Plasma Arc Vitrification)

- Demonstration Bulletin (EPA/540/M5-91/007)
- Technology Evaluation -Vol. 1 (EPA/540/5-91/007a)³
PB92-216035
- Technology Evaluation Vol. 11 (EPA/540/5-91/007b)³
PB92-216043
- Applications Analysis (EPA/540/A5-91/007)
PB92-218791
- Technology Demo Summary (EPA/540/S5-91/007)

Risk Reduction Engineering Laboratory

- and IT Corporation - Debris Washing System

- Technology Evaluation -Vol. 1 (EPA/540/5-91/006a)
- Technology Evaluation Vol. 11 (EPA/540/5-91/006b)³
PB91-231464
- Technology Demo Summary(EPA/540/S5-91/006)

- and University of Cincinnati-Hydraulic Fracturing of Contaminated Soil

- Demonstration Bulletin (EPA/540/MR-93/505)
- Technology Evaluation and Applications Analysis Combined (EPA/540/R-93/505)
- Technology Demo Summary(EPA/540/SR-93/505)

-and USDA-Forest Products Technology - Fungal Treatment Technology

- Demonstration Bulletin (EPA/540/MR-93/514)

-Mobile Volume Reduction Unit at the Sand Creek Superfund Site

- Treatability Study Bulletin (EPA/540/MR-93/512)

-Mobile Volume Reduction Unit at the Escambia Superfund Site

- Treatability Study Bulletin (EPA/540/MR-93/511)

-Volume Reduction Unit

- Demonstration Bulletin (EPA/540/MR-93/508)
- Applications Analysis (EPA/540/AR-93/508)
- Technology Evaluation (EPA/540/R-93/508)³
PB94-136264
- Technology Demo Summary(EPA/540/SR-93/508)

Roy F. Weston, Inc.

-and IEG Technologies-Unterdruck-Verdampfer-Brunner Technology (UVB) Vacuum Vaporizing Well

- Demonstration Bulletin (EPA/540/MR-95/500)
- Capsule (EPA/540/R-95/500a)

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Demonstration Project Results (Continued)

Low Temperature Thermal Treatment (LT3) System

- Demonstration Bulletin (EPA/540/MR-92/019)
- Applications Analysis (EPA/540/AR-92/019)

SBP Technologies, Inc.-Membrant Filtration and Bioremediation

- Demonstration Bulletin (EPA/540/MR-92/014)
- Applications Analysis (EPA/540/AR-92/014)

SilicateTechnology Corporation-Solidification/Stabilization of Organic/Inorganic Contaminants

- Demonstration Bulletin (EPA/540/MR-92/010)
- Applications Analysis (EPA/540/AR-92/010)³
PB93-172948
- Technology Evaluation (EPA/540/R-92/010)³
PB95-255709
- Technology Demo Summary(EPA/540/SR-92/010)

Simplot, J.R. - Ex Situ Anaerobic Bioremediation Technology: TNT

- Demonstration Bulletin (EPA/540/MR-95/529)
- Capsule (EPA/540/MR-95/529a)
- Innovative Tech. Eval. Report (EPA/540/R-95/529)

Simplot, J.R. - Ex-Situ Anaerobic Bioremediation System (The SABRE Process)

- Demonstration Bulletin (EPA/540/MR-94/508)
- Capsule (EPA/540/R-94/508a)
- Innovative Tech. Eval. Report (EPA/540/R-94/508)

Soiltech ATP Systems, Inc.

-Aostra-SoilTech Anaerobic Thermal Process

- Demonstration Bulletin (EPA/540/MR-92/008)

-SoilTech Anaerobic Thermal Processor

- Demonstration Bulletin (EPA/540/MR-92/078)

Soliditech, Inc. - Solidification and Stabilization

- Technology Evaluation -Vol. 1
(EPA/540/5-89/005a)³ PB90-191750
- Technology Evaluation Vol. 11
(EPA/540/5-89/005b)³ PB90-191768
- Applications Analysis (EPA/540/A5-89/005)
- Technology Demo Summary(EPA/540/S5-89/005)³
- Demonstration Bulletin (EPA/540/M5-89/005)³

Sonotech, Inc. - Cello Pulse Combustion Burner System

- Demonstration Bulletin (EPA/540/MR-95/502)
- Capsule (EPA/540/R-95/502a)

TerraKleen Response Group, Inc. - Solvent Extraction Treatment System

- Demonstration Bulletin (EPA/540/MR-94/521)³
- Capsule (EPA/540/R-94/521a)

Terra Vac, Inc. - in Situ Vacuum Extraction

- Demonstration Bulletin (EPA/540/M5-89/003)³
- Technology Evaluation -Vol. 1 (EPA/540/5-89/003a)³
PB89-192025
- Technology Evaluation Vol. 11 (EPA/540/5-89/003b)³
PB89-192033
- Applications Analysis (EPA/540/A5-89/003)
- Technology Demo Summary(EPA/540/S5-89/003)

Texaco, Inc. - Entrained-Bed Gasification Process

- Demonstration Bulletin (EPA/540/MR-94/514)
- Capsule (EPA/540/R-94/514a)
- Innovative Tech. Eval. Report (EPA/540/R-94/514)

Thorneco, Inc. - Enzyme - Activated Cellulose Technology

- Treataability Study Bulletin (EPA/540/MR-92/018)³

Toronto Harbour Commission - Soil Recycling Treatment Train

- Demonstration Bulletin (EPA/540/MR-92/015)
- Applications Analysis (EPA/540/AR-93/517)
- Technology Evaluation (EPA/540/R-93/517)³
PB93-216067
- Technology Demo Summary(EPA/540/SR-93/517)

Toxic Treatments USA, Inc. (Now NOVATERRA, Inc.)

- In-Situ Steam/Hot Air Stripping

- Demonstration Bulletin (EPA/540/M5-90/003)
- Applications Analysis (EPA/540/A5-90/008)

Ultrrox, a Division of Zimpro Environmental, Inc. - UV Ozone Treatment for Liquids

- Demonstration Bulletin (EPA/540/M5-89/012)
- Applications Analysis (EPA/540/A5-89/012)
- Technology Evaluation (EPA/540/5-89/012)³
PB90-198177
- Technology Demo Summary(EPA/540/S5-89/012)

U.S. EPA - McColl Superfund Site - Demonstration of a Trial Excavation

- Technology Evaluation (EPA/540/5-92/015)³
PB92-226448
- Applications Analysis (EPA/540/AR-92/015)
- Technology Demo Summary(EPA/540/SR-92/015)

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Wheelabrator Clean Air Systems, Inc. (formerly Chemical Waste Management, Inc.) -PO*WW*ER™

Technology

- Demonstration Bulletin (EPA/540/MR-93/506)
- Applications Analysis (EPA/540/AR-93/506)
- Technology Evaluation -Vol. 1
(EPA/540/R-93/506a)³ PB94-160637
- Technology Evaluation Vol. 11
(EPA/540/R-93506b)³ PB94-160660
- Technology Demo Summary(EPA/540/SR-93/506)

Zenon Environmental, Inc. - Zenon Cross- Flow Pervaporation Technology

- Demonstration Bulletin (EPA/540/MR-95/511)
- Capsule (EPA/540/R-95/511a)

Zenon Environmental Systems - Zenogem

Wastewater Treatment Process

- Demonstration Bulletin (EPA/540/MR-95/503)
- Capsule (EPA/540/R-95/503a)

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Emerging Technologies Program Reports

General Publications

- Superfund Innovative Technology Evaluation Program: - Innovation Making a Difference Emerging Tech. Brochure (EPA/540/F-94/505)
- Superfund Innovative Technology Evaluation Program: - Technology with an Impact Emerging Tech. Brochure (EPA/540/F-93/500)
- SITE Emerging Technology Program (Brochure) (EPA/540/F-95/502)

ABB Environmental Services, Inc. - Two Zone PCE Bioremediation System

- Emerging Tech. Bulletin (EPA/540/F-95/510)

Aluminum Company of America - Bioscrubber for Removing Hazardous Organic Emission from Soil, Water, and Air Decontamination Process

- EmergingTech. Report (EPA/540/R- 93/521)³ PB93-227025
- Emerging Tech. Bulletin (EPA/540/F-93/507)
- Emerging Tech. Summary (EPA/540/SR-93/521)
- Journal Article AWMA Vol. 44, No. 3, March 1994

Atomic Energy of Canada, Limited - Chemical Treatment and Ultrafiltration

- Emerging Tech. Bulletin (EPA/540/F-92/002)

Babcock & Wilcox Co. - Cyclone Furnace (Soil Vitrification)

- EmergingTech. Report (EPA/540/R- 93/507) PB93-163038
- Emerging Tech. Bulletin (EPA/540/F-92/010)
- Emerging Tech. Summary (EPA/540/SR-93/507)

Batelle Memorial Institute - In Situ Electroacoustic Soil Decontamination

- Emerging Technology (EPA/540/5-90/004)³ PB90-204728
- Emerging Tech. Summary (EPA/540/S5-90/004)³

Bio-Recovery Systems, Inc. - Removal and Recovery of Metal Ions from Groundwater (AlgaSORB)

- Emerging Technology (EPA/540/5-90/005a)
- Emerging Tech. - Appendices (EPA/540/5-90/005b)³ PB90-252602
- Emerging Tech. Summary (EPA/540/S5-90/005)
- Emerging Tech. Bulletin (EPA/540/F-92/003)

Biotrol, Inc. - Mehanotrophic Bioreactor System

- Emerging Tech. Bulletin (EPA/540/F-93/506)
- Emerging Tech. Summary (EPA/540/SR-93/505)
- Journal Article AWMA Vol. 45, No.1, Jan. 1995

Center for Hazardous Materials Research

- Acid Extraction Treatment System for Treatment of Metal Contaminated Soils
- Emerging Tech. Report (EPA/540/R-94/513)³ PB94-188109
- Emerging Tech. Summary (EPA/540/SR-94/513)

- Reclamation of Lead from Superfund Waste Material Using Secondary Lead Smelters

- Emerging Tech. Bulletin (EPA/540/F-94/510)
- Emerging Tech. Summary (EPA/540/SR-95/504)
- Emerging Tech. Report (EPA/540/R-95/504)³ PB9-199022

Colorado School of Mines - Constructed Wetlands-Based Treatment

- Emerging Tech. Bulletin (EPA/540/F-92/001)
- Emerging Tech. Summary (EPA/540/SR-93/523)
- Emerging Tech. Report (EPA/540/R-93/523)³ PB93-233914

University of Dayton Research Institute - Development of a Photothermal Detoxification Unit

- Emerging Tech. Bulletin (EPA/540/F-95/505)
- Emerging Tech. Summary (EPA/540/SR-95/526)
- Emerging Tech. Report (EPA/540/R-95/526)³ PB95-255733

Electro-Pure Systems, Inc. - Alternating Current Electrocoagulation Technology

- Emerging Tech. Bulletin (EPA/540/F-92/011)
- Emerging Tech. Summary (EPA/540/S-93/504)
- Journal Article AWMA V43, No. 43, May 1993

Electrokinetics, Inc., - Electrokinetic Soil Processing

- Emerging Tech. Bulletin (EPA/540/F-95/504)

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Energy and Environmental Engineering - Laser-Induced Photochemical Oxidative Destruction

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- Emerging Tech. Report (EPA/540/R-92/080)³
PB93-131431

Energy and Environmental Research Corporation - Hybrid Fluidized Bed System

- Emerging Tech. Bulletin (EPA/540/F-93/508)

FERRO Corporation - Waste Vitrification Through Electric Melting

- Emerging Tech. Bulletin (EPA/540/F-95/503)

Florida International University (or Electron Beam Research Facility)

- Electron Beam Treatment for Removal of Benzene and Toluene from Aqueous Streams and Sludge

- Emerging Tech. Bulletin (EPA/540/F-93/502)

- Electron Beam Treatment for the Trichloroethylene and Tetrachloroethylene from Aqueous Stream

- Emerging Tech. Bulletin (EPA/540/F-92/009)

- Removal of Phenol from Aqueous Solutions Using High Energy Electron Beam Irradiation

- Emerging Tech. Bulletin (EPA/540/F-93/509)

Institute of Gas technology

- Chemical and Biological Treatment (CBT)

- Emerging Tech. Bulletin (EPA/540/F-94/504)

- Fluid Extraction-Biological Degradation Process

- Emerging Tech. Bulletin (EPA/540/F-94/501)

IT Corporation - Photolysis/Biodegradation of PCB and PCDD/PCDF Contaminated Soils

- Emerging Tech. Bulletin (EPA/540/F-94/502)
- Emerging Tech. Summary (EPA/540/SR-94/531)
- Emerging Tech. Report (EPA/540/R-94/531)³
PB95-159992

IT Corporation - Process for the Treatment of Volatile Organic Carbon & Heavy-Metal Contaminated Soil

- Emerging Tech. Bulletin (EPA/540/F-95/509)

J.R. Simplot - Anaerobic Destruction of Nitroaromatics (the SABRE Process)

- Journal Article App.Env.Micro, Vol. 58, pp. 1683-89

Matrix Photocatalytic, Inc. - Photocatalytic Water Treatment

- Journal Article (EPA/600/A-93/282)³
PB94-130184

Membrane Technology and Research, Inc. - Volatile Organic Compound Removal from Air Streams by Membrane Separation

- Emerging Tech. Bulletin (EPA/540/F-94/503)

M.L. Energia- Reductive Photo-Dechlorination Process for Safe Conversion of Hazardous Chlorocarbon Waste Streams

- Emerging Tech. Bulletin (EPA/540/F-94/508)

New Jersey Institute of Technology - GHEA Associates Process for Soil Washing and Wastewater Treatment

- Emerging Tech. Bulletin (EPA/540/F-94/509)

PURUS, Inc. - Photolytic Oxidation Process [Destruction of Organic Contaminants in Air Using Advanced Ultraviolet Flashlamps]

- Emerging Tech. Bulletin (EPA/540/F-93/501)
- Emerging Tech. Summary (EPA/540/SR-93/516)
- Emerging Tech. Report (EPA/540/R-93/516)
PB93-205383

Roy F. Weston, Inc. - Ambersorb 563 Adsorbent

- Emerging Tech. Bulletin (EPA/540/F-95/500)
- Emerging Tech. Summary (EPA/540/SR-95/516)
- Emerging Tech. Report (EPA/540/R-95/516)³
PB95-264164

University of Washington - Metals Treatment at Superfund Sites by Adsorptive Filtration

- Emerging Tech. Bulletin (EPA/540/F-92/008)
- Emerging Tech. Summary (EPA/540/SR-93/515)
- Emerging Tech. Report (EPA/540/R-93/515)³
PB94-170230

Wastewater Technology Centre - [A] Cross-Flow Pervaporation System [for Removal of VOC's from Contaminated Water]

- Emerging Tech. Bulletin (EPA/540/F-93/503)
- Emerging Tech. Summary (EPA/540/SR-94/512)
- Emerging Tech. Report (EPA/540/R-94/512)³
PB95-170230

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PCP/PCB Immunoassay Test Kits

**PCP Immunoassay Technologies: Ensys Inc. - PENTA
Risc: Ohmicron Corp., - Penta RaPid; Millipore Inc. -
Envirogard**

- Demonstration Bulletin (EPA/540/MR-95/514)
- Innovative Tech. Eval. Report (EPA/540/R-95/514)

HNU-Hanby PCP Immunoassay Test Kit

- Demonstration Bulletin (EPA/540/MR-95/515)
- Innovative Tech. Eval. Report (EPA/540/R-95/515)

EnviroGard PCB Test Kit - Millipore Inc.

- Demonstration Bulletin (EPA/540/MR-95/517)
- Innovative Tech. Eval. Report (EPA/540/R-95/517)

Char-N-Soil PCB Test Kit

- Demonstration Bulletin (EPA/540/MR-95/518)
- Innovative Tech. Eval. Report (EPA/540/R-95/518)

Analytical Methods

Field Analytical Screening Program (FASP): PCB Method

- Demonstration Bulletin (EPA/540/MR-95/521)
- Innovative Tech. Eval. Report (EPA/540/R-95/521)

Field Analytical Screening Program (FASP): PCP Method

- Demonstration Bulletin (EPA/540/MR-95/528)
- Innovative Tech. Eval. Report (EPA/540/R-95/528)

ConePenetrometer

The Rapid Optical Screening Tool (ROST)

- Demonstration Bulletin (EPA/540/MR-95/519)
- Innovative Tech. Eval. Report (EPA/540/R-95/519)

Site Characterization Analysis Penetrometer System

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United States
Environmental
Protection Agency

EPA 542-N-97-007
February 1997

Solid Waste And Emergency Response (5102G)

 **EPA Vendor FACTS 2.0 Bulletin**

Vendor FACTS

**A Database of Innovative Site Characterization
Technologies and Vendors**

Vendor Field Analytical and Characterization
Technologies System

Developed by EPA's Technology Innovation Office and
National Exposure Research Laboratory - Las Vegas

For Technology USERS



► How can I select the most appropriate technology for site characterization?

Use EPA's Vendor Field Analytical and Characterization Technologies System Database (Vendor FACTS).

Developed by EPA's Technology Innovation Office and National Exposure Research Laboratory - Las Vegas and offered to users at no charge, Vendor FACTS contains information provided by vendors on the applicability, performance, and current use of their products. The user friendly system allows users to screen technologies by such parameters as contaminants, media, intended use or development status. Version 2.0 includes approximately 128 technologies provided by 92 vendors.

Version 2.0 contains analytical, geophysical, chemical extraction, and sampling technologies

The database contains information on certain categories of technologies that EPA believes may provide the greatest opportunities for streamlining the site assessment process. Some of the technologies are listed below:

- Air Measurement
 - Analytical Detectors
 - Gas Chromatography
 - Chemical Reaction-Based Indicators
 - Immunoassay
 - Soil Gas Analyzer
 - Cone Penetrometer
 - Downhole Sensors
 - X-Ray Fluorescence Analyzer
 - Ground Penetrating Radar
 - Infrared Monitors

Build A Search		
Filter Information		
Vendor Name	Search by Technology Type	
Select an item from the list or Enter the first letter to locate.		
<input type="text" value="Search for Type..."/> <div style="border: 1px solid black; padding: 5px; margin-top: 5px;"> Air Measurement Analytical Detectors Analytical Traps Biosensors Chemical Reaction-Based Indicators Cone Penetrometer Chemical Sensors Downhole Sensors - Saturated Zone Downhole Sensors - Vadose Zone Electromagnetic Sounding Geo-Datum Chemical Sensors and Analyses </div>		
Technology Type	<input type="button" value="Clear All"/> <input type="button" value="OK"/> <input type="button" value="Cancel"/>	
Technology Maturity		
Media		
Monitoring Target		
Waste Source		
Intended Use		
Data Quality Use		
Selected Criteria		
Media =	Soil [in situ] [Actual]. or. Ground Water [Actual]	
AND.		
Monitoring Target =	Halogenated volatiles [Actual]. or. PCBs [Actual]. or.	
<input type="button" value="Search"/> <input type="button" value="Clear"/> <input type="button" value="Close"/>		

Comprehensive Search Capabilities

The database enables users to develop customized searches on such criteria as: Technology Type, Media Contaminants, Intended Use (e.g. Field Screening, Risk Assessment), Performance, and Cost Data.

For Technology VENDORS

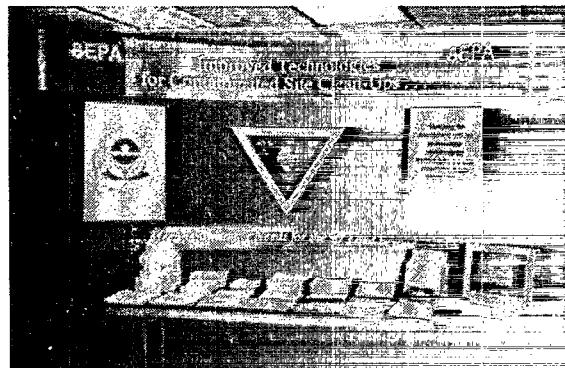
- ***Do site managers know about the capabilities and performances of your latest technologies?***

Vendor FACTS connects you with potential customers

EPA believes that Vendor FACTS reaches a substantial number of professionals involved in site characterization and analysis in the field. Users of the system, such as state and federal regulators, site managers, consulting firms, and remediation professionals, have access to and are able to share information about your products and their capabilities.

- ***Why should you promote your technologies through Vendor FACTS?***

- Participation in Vendor FACTS is FREE
- EPA promotes and demonstrates the system at various conferences in the U.S. and abroad.
- More than 100 of your competitors are using Vendor FACTS to promote their technologies. (A complete list of Vendor FACTS 2.0 vendors is provided in this bulletin.)



EPA Technology Innovation Office Conference Exhibit

- ***What technologies are included in Vendor FACTS?***

Vendor FACTS is a service offered by EPA to promote the use of certain categories of innovative technologies for field analysis and site characterization. It includes portable or transportable technologies for on-site screening, characterizing, monitoring and analysis of hazardous substances. Stand alone software used in the field to facilitate or expedite site characterization process also is included in the database. Technologies used for monitoring industrial process waste streams are not eligible.

- ***How can you participate in Vendor FACTS?***

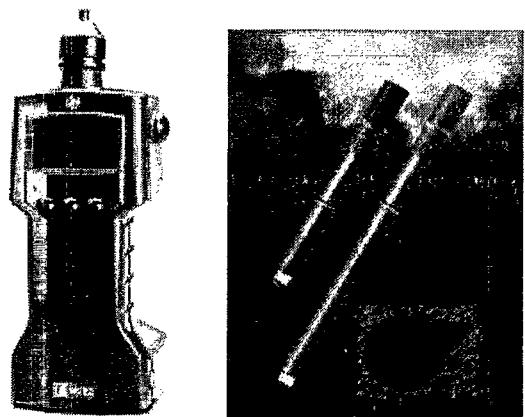
Participation in Vendor FACTS is voluntary, at no charge to the technology vendors. Vendors that wish to participate in Version 3.0 of the database must provide to EPA information about their site characterization technologies by completing the Vendor Information Form (VIF). The VIF, designed to allow vendors to highlight the performance of their technologies, can be obtained by returning the attached Order Form. The VIF 3.0 will be available by April 1997. Version 3.0 is scheduled for release in December 1997.

Disclaimer: This document has been approved for publication as an EPA report. Mention of trade names, commercial products or organizations should not be construed as approval or endorsement by EPA.

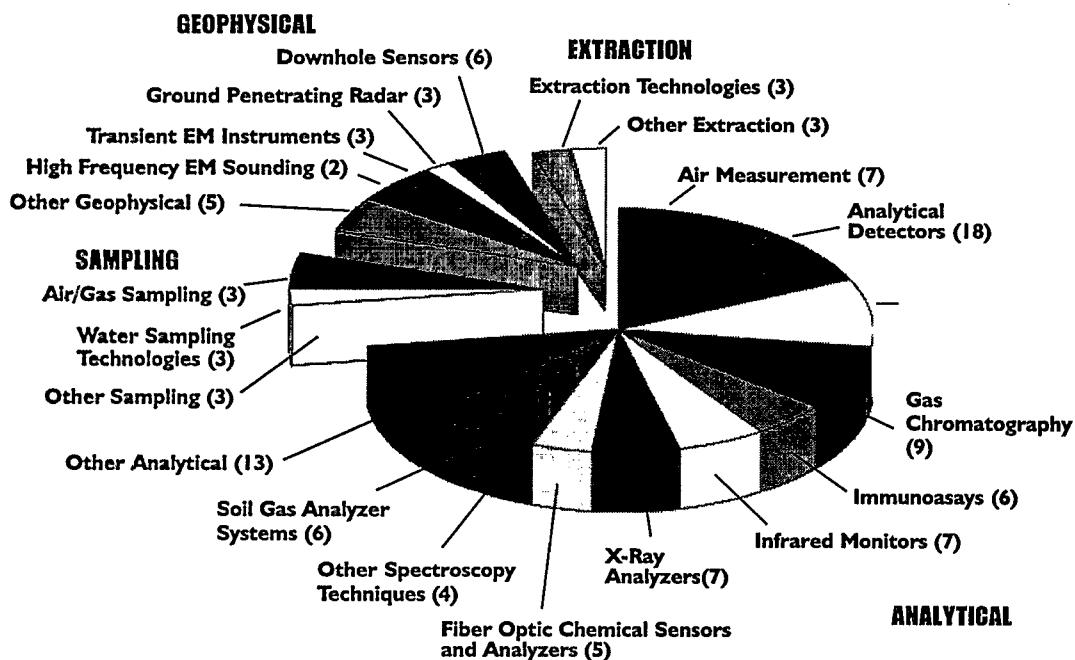
WHAT'S NEW FOR VERSION 2.0?

- 34 New Vendors... 92 in all
- 44 New Technologies... 128 in all
- Technology Pictures and Schematics

Downloadable from:
<http://www.ttemi.com/vfacts>
<http://clu-in.com>



VENDOR FACTS 2.0 TECHNOLOGY TYPES



SYSTEM REQUIREMENTS

Vendor FACTS 2.0 requires the following hardware and software capabilities:

- 386 class (or higher) personal computer
- 4 megabytes of random access memory (RAM)
- Windows™ 3.1 (or higher)
- 5 megabytes of free hard disk space

VENDOR FACTS REGISTRATION AND ORDER FORM

Please register using this form even if you have downloaded the software from an on-line service other than CLU-IN. Once registered, you will be notified about system updates.

Name _____

Date Ordered _____

Telephone No. _____ Fax No. _____

Company/Agency _____

Street _____

City _____ State _____ Zip Code _____

Country _____ E-mail Address _____

Please check all that apply:

- Register me as a Vendor FACTS user and send me information about system updates.
I was able to download Vendor FACTS 2.0 electronically.
- Send me the Vendor FACTS 2.0 diskettes (3.5").
- I am an innovative site characterization technology vendor and would like to be included in Vendor FACTS 3.0. Please place me on the mailing list to receive the Vendor Information Form (VIF) 3.0.

MAIL TO: U.S. EPA/NCEPI
P.O. Box 42419
Cincinnati, OH 45242-0419

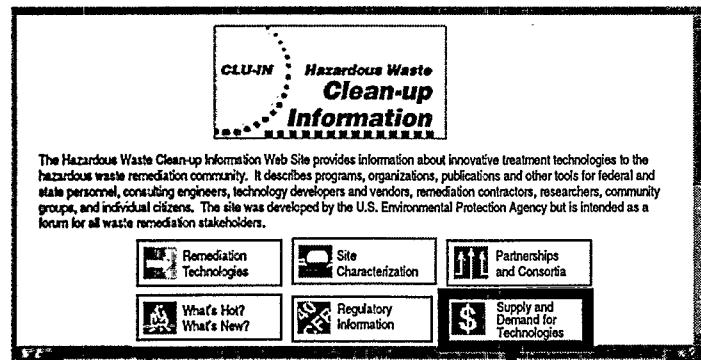
FAX TO: U.S. EPA/NCEPI
513-489-8695
513-489-8190 (verification)

For more information on:

- **Downloading the Vendor FACTS software**
- **Installing or operating Vendor FACTS**
- **Submitting information for Vendor FACTS 3.0**

Call the Vendor FACTS help line: 800-245-4505 or 703-287-8927

DOWNLOADING VENDOR FACTS 2.0



Internet Access -
EPA's Clean-up
Information Web Site -

<http://clu-in.com>

or the Vendor FACTS
Home Page -

[http://www.ttemi.com/
facts](http://www.ttemi.com/facts)

\$ Supply and Demand for Remediation Technologies
[Supply of Technologies] [Demand for Technologies] [Publications]

• The Supply of Innovative Technologies from Developers and Vendors

Vendor Field Analytical and Characterization Technologies System (Vendor FACTS) is a Windows-based system, released in December 1995, that provides vendors' information on field portable technologies for measuring and monitoring contaminated soil and groundwater at sites. Some of the representative technologies listed in the system include: air measurement, analytical detectors, gas chromatography, chemical reaction-based indicators, immunoassay, soil gas analyzers. The system is updated annually. The database is available for downloading from the Publications page below.

Vendor Information System for Innovative Treatment Technologies (VISITT) is a PC-based system containing information on 325 innovative remediation technologies offered by 204 vendors. The database is available for downloading from the website.

VendorFACTS
A service provided by the U.S. EPA's Technology Innovation Office and National Exposure Research Laboratory, Las Vegas

A FREE Database of Innovative Field Analytical and Characterization Technologies for microsoft Windows

Cost and performance data on more than 120 hazardous waste characterization technologies

Vendor FACTS 2.0 Software
To Download the Vendor FACTS 2.0 for Windows database software, click here → **Download**

VENDORS AND TECHNOLOGY LIST

Air Measurement

ESCO Electronics & Associates, Inc.
Insitec Measurement Systems, Inc.
Supelco, Inc.
Tekran, Inc.
Testo, Inc.
Xontech, Inc.

Air/Gas Sampling Technologies

ALPHA M.O.S.
SKC Inc.

Analytical Detectors

Arizona Instrument Corporation
Automata, Inc.
Cincinnati Electronics Corporation
Dexsil Corporation

Heath Consultants, Inc.

Holguin, Fahan, and Associates, Inc.
Palitest, Ltd.
Photographic Analysis Company, Inc.
Photovac Monitoring Instruments
Physical Sciences Incorporated
RAE Systems, Inc.
The Foxboro Company
Thermo Environmental Instruments, Inc.
Turner Designs

Biosensors

AZUR Environmental
Group 206 Technologies, Inc.

Borehole Technologies
SimulProbe Technologies, Inc.

Chemical Reaction-Based Indicators

Dexsil Corporation
Gallard-Schlesinger Industries, Inc.
Envirol, Inc.
Hanby Environmental Laboratory Procedures, Inc.
(H.E.L.P.)
Invitro International
Mercury Science, Inc.
Neogen Corporation
ORS Environmental Systems
Sensidyne, Inc.

Cone Penetrometer Chemical Sensors
Geoprobe Systems

Downhole Sensors

BioRenewal Technologies Inc.
Keck Instruments, Inc.
Solinst Canada, Ltd.
Troxler Electronic Laboratories, Inc.
Yellow Springs Instrument Co., Inc. (YSI)

Electrochemical-based Detectors
Palintest, Ltd.

Extraction Technologies (Analytical Traps)
Analytical and Remedial Technology, Inc.
Supelco, Inc.
Xonitech, Inc.

Fiber Optic Chemical Sensors and Analyzers
FCI Environmental, Inc.
Noverflo, Inc.
O.K. Optik Keramik Technologies GmbH
ORS Environmental Systems
Savannah River Technology Center

Gas Chromatography

EST, Inc.
MTI Analytical Instruments
Photovac Monitoring Instruments
Sensidyne, Inc.
Sentex Systems, Inc.
SRI Instruments
Tracer Research Corporation

Ground Penetrating Radar

GEO-CENTERS, INC.
Geophysical Survey Systems, Inc.
Microgeophysics Corporation (MGC)

High Frequency Electromagnetic Sounding
Geonics Ltd.
Microgeophysics Corporation (MGC)

Immunoassays

BioNebraska, Inc
Strategic Diagnostics Incorporated
New Horizons Diagnostics Corporation

Infrared Monitors

Carala Air Associates (formerly ETG)
Cincinnati Electronics Corporation
General Analysis Corporation
SCI-TEC Instruments USA, Inc.
The Foxboro Company
Wilks Enterprises, Inc.

Ion Mobility Spectroscopy
Molecular Analytics, LLC (Formerly ETG)
PCP, Inc.

Mass Spectrometry
Bruker Anal. Sys., Inc. and BFA, GMBH
Eco Logic
Viking Instruments Corporation

Moisture Analysis
Zeltex, Inc.

Other Spectroscopy Techniques
Aurora Instruments Ltd.
Hanby Environmental Laboratory Procedures, Inc.
(H.E.L.P.)
TherMold Partners, L.P.
Universal Systems, Inc.

Seismic Reflection/Refraction
Resolution Resources, Inc.

Software
CoreGroup Services, Inc.

Soil Gas Analyzer Systems
ASIST Inc.
Columbus Instruments
Holguin, Fahan, & Associates, Inc.
Quadrel Services, Inc.
Tracer Research Corporation
TVG Environmental, Inc.

Soil Sampling
Warrington Ecological Systems Analysis (WECSA)

Solid Phase Extraction
Supelco, Inc.

Subsurface Electromagnetic
Geophex, Ltd.
WMI International, Inc.

Subsurface Magnetometry
GEO-CENTERS, INC.
Scintrex Ltd.

Thermal Desorption
Supelco, Inc.

Transient Electromagnetic (EM)
Geophysical Instruments
Geonics Ltd.
Schonstedt Instrument Company
Westec

Water Sampling Technologies
Keck Instruments, Inc.
Margan M.L.S (1994) Ltd.
Spectrex

X-Ray Fluorescence Analyzers
Advanced Analytical Products & Services
Asoma Instruments, Inc.
Metorex Inc.
Niton Corporation
Rigaku USA, Inc.
Scitec Corporation
Spectrace Instruments
TN Spectrace

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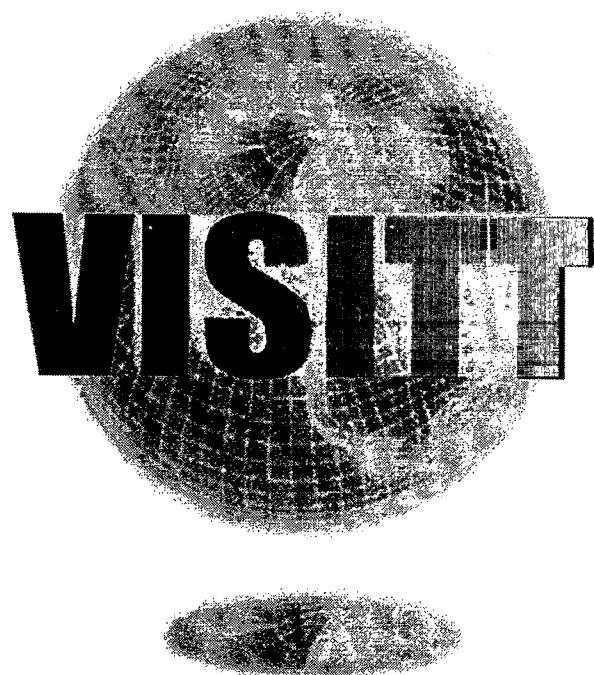
United States
Environmental
Protection Agency

EPA-542-N-96-006
September 1996

Solid Waste And Emergency Response (5102G)



An Electronic Yellow Pages Of Innovative Treatment Technologies and Vendors



**Vendor Information System for
Innovative Treatment Technologies**

Technology Innovation Office

REMEDIATION PROFESSIONALS

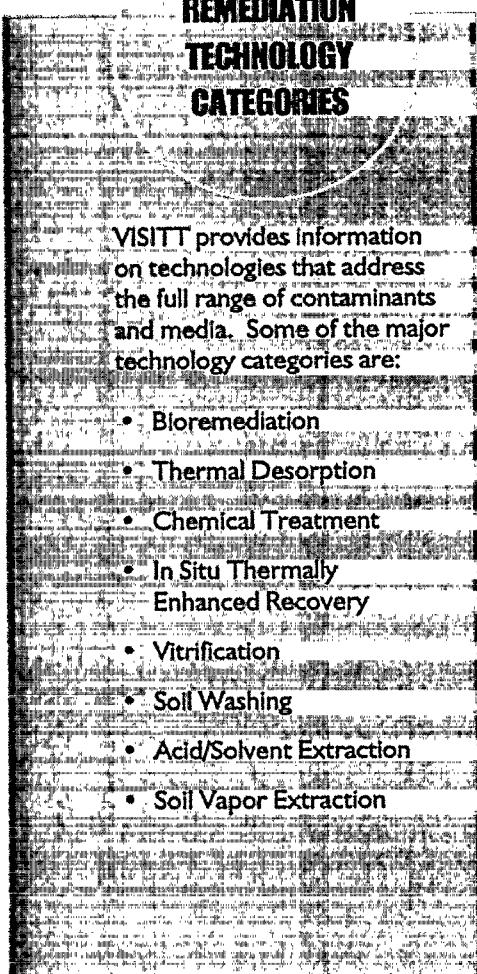
Are you often faced with the time-consuming task of identifying and selecting remediation technologies and vendors?

► VISITT 5.0 - Vendor Information System for Innovative Treatment Technologies - can help.

Offered by the U.S. EPA's Technology Innovative Office (TIO), VISITT Version 5.0 is a user-friendly database providing data on 346 innovative treatment technologies (75% of which are commercially available) provided by 210 vendors.

VISITT contains detailed information provided by vendors that enables you to screen and assess remediation technologies quickly. The General Vendor Information screen below shows the information options provided for each technology.

GENERAL VENDOR INFORMATION		
ABC ENVIRONMENTAL, INC. CHEMICAL TREATMENT - OTHER		
Trade Name:	ABC (TM)	Updated: 8/15/96
Vendor Address:	528 ABC Drive McLean, VA 22102, USA Emily Burke	
Contact: (p) : (703) 522-1722 (f) : (703) 522-1721	E-Mail : burke@abcentv.com Web : www.abcentv.com	
EPA SITE Emerging Technology Program	Yes	Registered Trademark : Yes
EPA SITE Demonstration Program	No	Technology Patented : Yes
Small Business	No	Patent Pending : No
SIC Code(s)	8711	Exclusive License : Yes
Scale	Full-Scale	
Other Information Options		
Description	Waste Applications	Bench-Scale Information
Highlights	Representative Projects	Pilot-Scale Information
Limitations	Estimated Price Range	Full-Scale Information
Other Comments	Technical References	Process Flow Diagrams



CUSTOMIZED SEARCH CAPABILITIES

VISITT 5.0	
Waste/Technology/Vendor Site Reports Features Registration Quit	
<input type="button" value="Search by Waste/Technology/Vendor"/> Contaminant Group Contaminant Data Media Waste Source Technology Type Scale Vendor Name Trade Name State/Province Country Business Size	<input type="button" value="Search by Site"/> Site Name Cleanup Type State/Province Country Equipment Scale Waste Source Media Contaminant Data Regulation/Statute/Organization
Select Option with Cursor, [F1] for Help, [Esc] Backtrack	

INNOVATIVE TREATMENT TECHNOLOGY VENDORS

Are you looking for cost-effective ways to market your innovative treatment technologies to those directly involved in selecting hazardous waste remedies?

VISITT will share your technology capabilities with an estimated 12,000 users from 76 countries.

WHAT'S NEW FOR VISITT 5.0?

- **NEW VENDORS**
32 new, 210 in all
- **NEW TECHNOLOGIES**
56 new, 346 in all
- **VENDOR E-MAIL and WEB PAGE ADDRESSES**
- **DOWNLOADABLE FROM A DEDICATED VISITT HOME PAGE**
And other on-line resources
- **PROCESS FLOW DIAGRAMS and SCHEMATICS**
For over 90 technologies

WHY SHOULD YOU PROMOTE YOUR TECHNOLOGIES THROUGH VISITT?

- Participation in the database is FREE
- Gain more than 12,000 potential customers in the remediation community
- Join the ranks of more than 200 of your competitors who use VISITT to promote their technologies; complete list of VISITT 5.0 vendors is provided in this bulletin
- Current VISITT vendors reported receiving, on average, approximately two inquiries per month from VISITT users; a quarter of those vendors reported receiving job solicitations

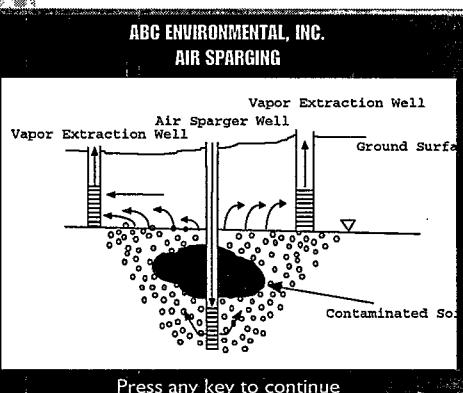
WHO IS ELIGIBLE TO PROMOTE THEIR TECHNOLOGIES IN VISITT?

Technologies are eligible if they are designed to remediate groundwater or nonaqueous phase liquids (NAPL) in situ, soil, sludge, solid-matrix waste, natural sediments, and off-gas. Technologies not eligible for VISITT include incineration, above-ground wastewater or groundwater treatments, solidification/stabilization, or treatment technologies designed for treating industrial waste.

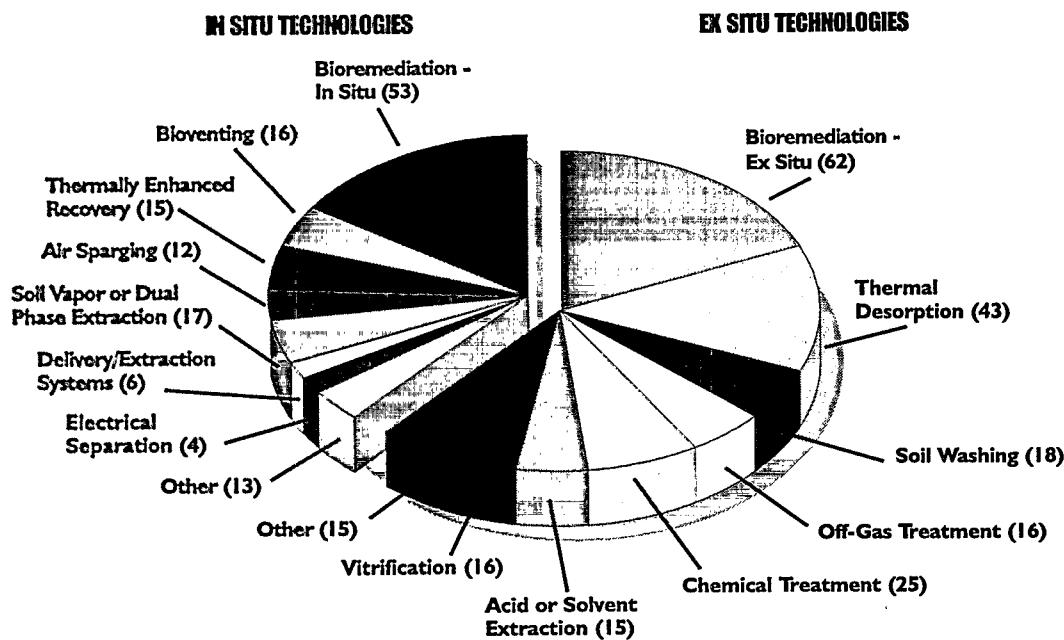
HOW TO SUBMIT TECHNOLOGY INFORMATION TO VISITT?

To submit information for listing in VISITT, vendors must complete a Vendor Information Form (VIF). EPA, which

updates VISITT annually, will be distributing the VIF 6.0 in March 1997. EPA plans to release VISITT 6.0 in the summer of 1997. See the order form for instructions on how to order the VIF.



VISITT 5.0 TECHNOLOGY TYPES



OBTAINING VISITT 5.0

ON-LINE: EPA has made the VISITT 5.0 database, user manual and Vendor Information Form (VIF) available for download (free) on the World Wide Web. Instructions for downloading are provided on the reverse of this panel. VISITT 5.0 software can be downloaded from the following:

CURRENT:

- www.prcemi.com/visitt
VISITT Home Page
- www.clu-in.com
EPA's Clean-Up Information
(CLU-IN) Web Site
- The Alternative Treatment Technologies
Information Center (ATTIC) 703-908-2138

FUTURE (December 1996):

- www.epa.gov
EPA Home Page
- America Online (AOL)

For instructions on downloading from these resources, contact the VISITT HELP LINE at 800-245-4505 or 703-287-8927.

DISKETTES: Use the form provided in this bulletin to order the VISITT 5.0 diskettes and user manual.

SYSTEM REQUIREMENTS

VISITT 5.0 requires the following hardware and software capabilities:

- 386 class (or higher) personal computer
- 640K of random access memory (RAM)
- DOS 3.3 (or higher)
- 10 megabytes of free hard disk space

Disclaimer: This document has been approved for publication as an EPA report. Mention of trade names, commercial products or organizations should not be construed as approval or endorsement by EPA.

VISITT 5.0 Registration & 3.5" Diskette Order Form

Please use this form to register if you have downloaded the software and have not registered as a VISITT user through the CLU-IN or VISITT web sites. When registered, you will be notified about system updates.



MAIL TO: U.S. EPA/NCEPI
P.O. Box 42419
Cincinnati, OH 45242-0419

FAX TO: U.S. EPA/NCEPI
513-489-8695
513-489-8190 (verification)

Please type or print legibly. Allow 4-6 weeks for delivery of diskettes and user manual.

Name _____

Date Ordered _____

Telephone No. _____ Fax No. _____

Company/Agency _____

Street _____

City _____ State _____ Zip Code _____

Country _____ E-mail Address _____

Please check all that apply:

- Register me as a VISITT user and send me information about system updates. I was able to download VISITT 5.0 electronically.
- Send me the VISITT 5.0 diskettes (3.5").
- Send me a VISITT 5.0 user manual.
- I am an innovative treatment technology vendor and would like to be included in VISITT Version 6.0. Please place me on the mailing list to receive the Vendor Information Form (VIF) 6.0.

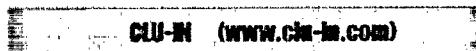
For more information on:

- **Downloading the VISITT software**
- **Installing or operating VISITT**
- **Submitting information for VISITT 6.0**

Call the VISITT help line:

800-245-4505 OR 703-287-8927

DOWNLOADING THE VISITT 5.0 SOFTWARE



CLU-IN is accessible through the World Wide Web at www.ciu-in.com. The VISITT database, user manual, and Vendor Information Form (VIF) can be downloaded from the CLU-IN web site. The user manual is in WordPerfect 6.1 format. CLU-IN also can be accessed through a direct modem access number (301-589-8366).

To download the VISITT software from the CLU-IN home page, perform the following steps:

- STEP 1: Connect with the web site at www.ciu-in.com.
- STEP 2: Click on the **Supply and Demand for Technologies** icon.
- STEP 3: Click on the **Vendor Information System for Innovative Technologies (VISITT)**.
- STEP 4a: Click on the **VISITT Information Web Site** and then click on the **Download** button for the **VISITT 5.0 Software**.

or STEP 4b: Click on the **Download VISITT 5.0** hypertext.



In addition to CLU-IN, the VISITT home page enables users of the World Wide Web to download the VISITT database, user manual, and Vendor Information Form (VIF).

- STEP 1: Connect with the Home Page at www.ttemi.com/visitt.
- STEP 2: Click on the **Download** button that corresponds with the software you wish to download (**VISITT 5.0 database, User Manual, or Vendor Information Form**).

For more information or a copy of the downloading instructions, call the VISITT HELP LINE at **800-245-4505** or **703-287-8927**.



ABB Environmental Services, Inc.
Accutech Remedial Systems, Inc.
Advanced Environmental Services, Inc.

Advanced Recovery Systems, Inc.
AEA Technology
Alternative Remedial Technologies, Inc.

Alvarez Brothers, Inc.
AP Technologies, Inc.
Applied Remedial Technologies

Artech, Inc.

Ariel Industries, Inc.

Art International, Inc.

B&S Research, Inc.

B&W Nuclear Environmental Services, Inc.

Battelle Memorial Institute

Battelle, Pacific Northwest Division

Bearehaven Reclamation, Inc.

Beco Engineering Co.

Benchem

Bergmann USA

Billings & Associates, Inc.

Bio Solutions, Inc.

Bio-Electrics, Inc.

Bio-Genesis Technologies

Biogee International, Inc.

Bioremediation Service, Inc.
Bioremediation Technology Services, Inc.

Bogart Environmental Services, Inc.

Bohn Biofilter Corp.

Carlo Environmental Technologies, Inc.

Carson Environmental Caswan Environmental Services Ltd.

Center For Hazardous Materials Research

Chemcycle Environment, Inc.

Chempete, Inc.

Clayton Environmental Consultants

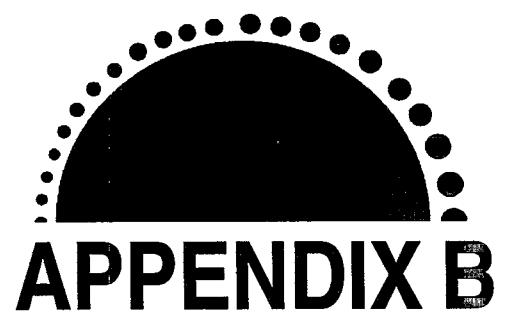
Clean-Up Technology, Inc.

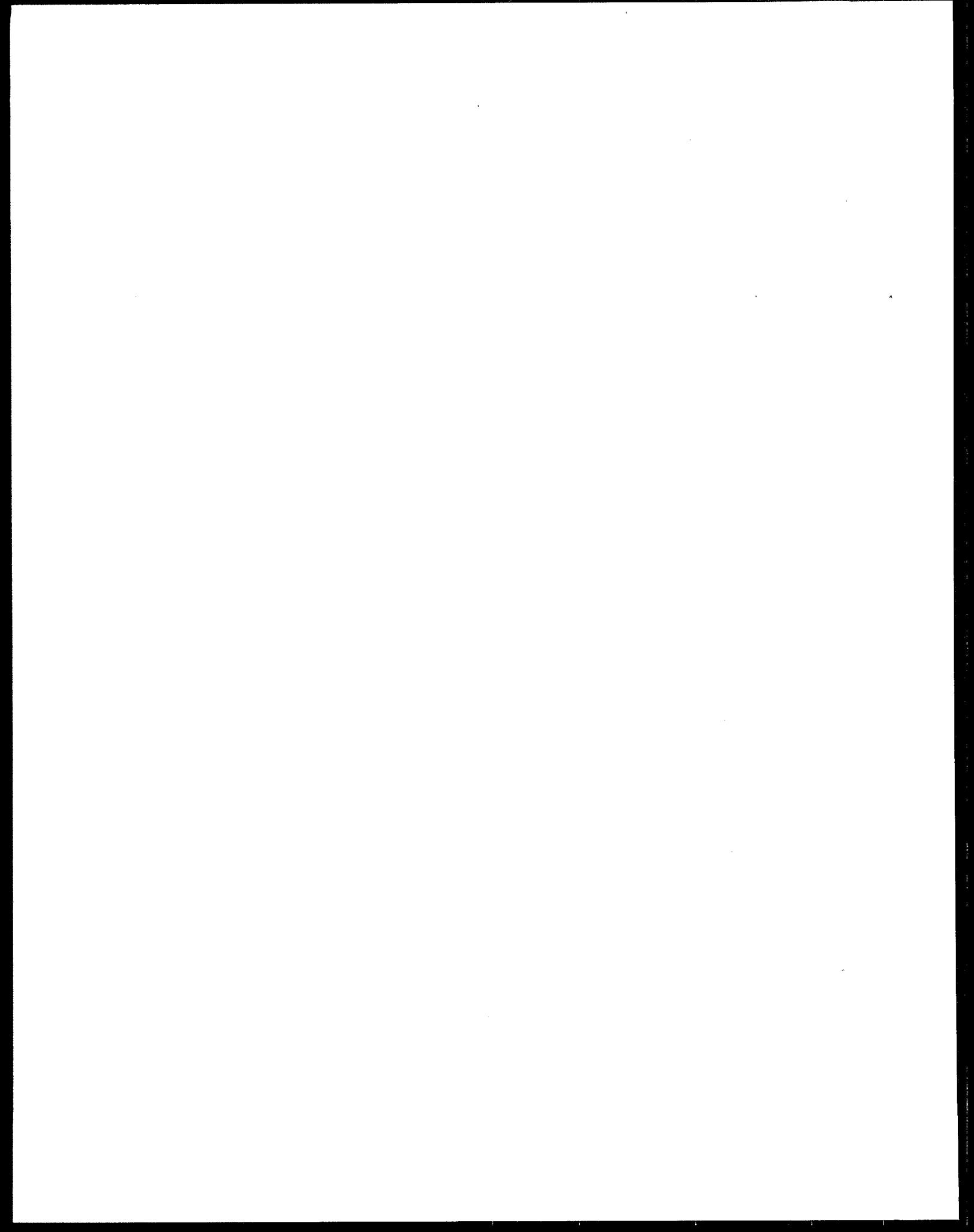
Clyde Engineering Service

VISIT 5.0 VENDORS (*continued*)

Comodore Applied Technologies, Inc.
Contech Environmental Services, Inc.
Corpex Technologies, Inc.
Covenant Environmental Technologies, Inc.
Dames & Moore
Day International - Environmental Div.
Dehydro-Tech Corporation
Delphi Research, Inc.
Directed Technologies Drilling, Inc.
Divesco, Inc.
Drilex Systems, Inc.
Duratherm, Inc.
Dynaphore, Inc.
Earth Decontaminators, Inc. (EDI)
Earthfax Engineering, Inc.
Eco-Tec, Inc./Ecology Technology
Ecology Technologies International, Inc.
Ecosite, Inc.
Ecotechniek B.V.
EET Corporation
EET, Inc.
EG & G Environmental, Inc.
Eimco Process Equipment Co.
Electro-Petroleum, Inc.
Electro-Pyrolysis, Inc.
Electrokinetics, Inc.
Eli Eco Logic International, Inc.
EN&C Engineering Associates
En-Dyn
Energy Reclamation, Inc.
ENSR Consulting and Engineering
Enviro-Klean Soils, Inc.
Envirogen, Inc.
Envirometal Technologies, Inc.
Enviroengineering
Environmental Fuel Systems, Inc.
Environmental Remediation Consultants, Inc.
Environmental Technologies International
EODT Services, Inc.
ESE Environmental, Inc.
ETEC
Etus, Inc.
First Environment, Inc.
Fluor Daniel GTI
G.E.M., Inc.
General Atomics
Geo-Con, Inc.
Geo-Microbial Technologies, Inc.
Geokinetics International Inc.
Geosafe Corporation
Grace Bioremediation Technologies
H2O Science, Inc.
Hazen Research, Inc.
High Voltage Environmental Applications
Horizontal Technologies, Inc.
Horsehead Resource Development Co., Inc.
Hrubetz Environmental Services, Inc.
Hydriplex, Inc.
IEG Technologies Corp.
IIT Research Institute
In-Situ Fixation, Inc.
Integrated Chemistries, Inc.
Integrated Environmental Solutions, Inc.
Integrity Engineering, Inc.
Intera, Inc.
IT Corporation
J.R. Simplot Company
KAI Technologies, Inc.
Kalkaska Construction Service, Inc.
Kap & Sepa, Ltd.
Keller Environmental Inc.
Kemron Environmental Services, Inc.
KSE, Inc.
KTR Environmental Services, Inc.
Law Engineering And Environmental Svc
Limnofix Inc./Golder Associates
Maxymillian Technologies, Inc.
MBI International
McLaren/Hart Environmental Engineering
Membrane Technology & Research, Inc.
Mercury Recovery Services, Inc.
Metcalf & Eddy, Inc.
Michigan Biotechnology Institute
Micro-Bac International, Inc.
Microbial Environmental Services (MES)
Microbial International
Microfluidics Corp.
Midwest Microbial, L.C.
Midwest Soil Remediation, Inc.
Molten Metal Technology, Inc.
Mycotech Corporation
Nucon International, Inc.
OHM Remediation Services Corporation
On-Site Technologies, Inc.
Parsons Engineering-Science, Inc.
Perino Technical Services, Inc.
Pet-Con Soil Remediation, Inc.
Philip Environmental Services Corp.
Phytokinetics, Inc.
Plasma Energy Applied Technology (Peat)
Portec, Inc.
Praxair, Inc.
Praxis Environmental Technologies, Inc.
Process Technologies, Inc.
Purgo, Inc.
Quaternary Investigations, Inc.
R.E. Wright Environmental, Inc. (REWEL)
Radian International LLC
RCRA Environmental, Inc.
Recycling Science International, Inc.
Remediation Technologies, Inc.
Remtech, Inc.
Resources Conservation Company
Retech, Div. Of M4 Environmental
RMT, Inc.
Roy F. Weston, Inc.
Rust International, Inc.
S.G. Frantz Co., Inc.
S.S. Papadopoulos & Associates, Inc.
Sanford Cohen And Associates, Inc.
SBP Technologies, Inc.
SDTX Technologies, Inc.
Seiler Pollution Control Systems, Inc.
Separation and Recovery Systems, Inc.
Sevenson Environmental Services, Inc.
Sive Services
Smith Environmental Technologies Corp.
Soil Remediation of Philadelphia, Inc.
Soil Solutions, Inc.
Soil Technology, Inc.
Soiltech ATP Systems, Inc.
Solucorp Industries Ltd.
Someus & Partners Unlimited
Southwest Soil Remediation, Inc.
SPI/Astec
SRE, Inc.
Stir-Melter, Inc.(Subsid/Glasstech, Inc.)
Surtek, Inc.
Sybron Chemicals, Inc.
Technology Scientific, Ltd.
Terra Concepts, Inc.
Terra Vac / Battelle PNL
Terra Vac, Inc.
Terra Verda Inc.
Terra-Kleen Response Group, Inc.
Texaco, Inc.
Texarome, Inc.
Texilla Environmental
The Doe Run Company
The Nature Tank Div. Of Cmh Envrmntl Grp.
Thermatrix, Inc.
Thermo Nutech
Thermochem, Inc
Thermotech Systems Corporation
TPS Technologies, Inc.
TVIES, Inc.
University of Dayton Research Institute
Vance IDS, Inc.
Vega Power Resources, Inc.
Vert
Viking Industries
VIT Incorporated
Vital Concepts, Inc.
Vortec Corporation
Wasatch Environmental, Inc.
Waste Destruction Technologies, Inc.
Waste Stream Technology, Inc.
Water And Slurry Purification Process
Western Research Institute
Westinghouse Remediation Services, Inc.
Yellowstone Environmental Science, Inc.
Zapit Technology, Inc.

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Appendix B**LIST OF ACRONYMS and GLOSSARY OF KEY TERMS**

ARAR	Applicable or Relevant and Appropriate Requirement	O&M	Operations and Maintenance
ASTM	American Society for Testing and Materials	ORD	Office of Research and Development
BDAT	Best Demonstrated Achievable Technology	OSWER	Office of Solid Waste and Emergency Response
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene	PAH	Polynuclear Aromatic Hydrocarbon
CAA	Clean Air Act	PA/SI	Preliminary Assessment and Site Inspection
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act	PCB	Polychlorinated Biphenyl
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System	PCP	Pentachlorophenol
CWA	Clean Water Act	PRP	Potentially Responsible Party
DDT	Dioxin	QA/QC	Quality Assurance and Quality Control
DNAPL	Dense Nonaqueous Phase Liquid	RCRA	Resource Conservation and Recovery Act
DQO	Data Quality Objective	RD/RA	Remedial Design and Remedial Action
EPA	U.S. Environmental Protection Agency	RI/FS	Remedial Investigation and Feasibility Study
ESA	Environmental Site Assessment	ROD	Record of Decision
HRS	Hazard Ranking System	RQ	Reportable Quantity
HSWA	Hazardous and Solid Waste Amendments	SARA	Superfund Amendments and Reauthorization Act
IRIS	Integrated Risk Information System	SITE	Superfund Innovative Technology Evaluation Program
ITT	Innovative Treatment Technology	SVE	Soil Vapor Extraction
LDR	Land Disposal Restrictions	SVOC	Semi-Volatile Organic Compound
LNAPL	Light Nonaqueous Phase Liquid	TCE	Trichloroethylene
LUST	Leaking Underground Storage Tank	TIO	Technology Innovation Office
NAPL	Nonaqueous Phase Liquid	TPH	Total Petroleum Hydrocarbon
NCP	National Contingency Plan	TSCA	Toxic Substances Control Act
NPDES	National Pollutant Discharge Elimination System	TSDF	Treatment, Storage, and Disposal Facility
NPL	National Priorities List	UST	Underground Storage Tank
NRC	National Response Center	VCP	Voluntary Cleanup Program
		VOC	Volatile Organic Compound

The following is a list of specialized terms used during the cleanup of Brownfields sites.

Absorption

Absorption is the passage of one substance into or through another.

Adsorption

Adsorption is the adhesion of molecules of gas, liquid, or dissolved solids to a surface. The term also refers to a method of treating wastes in which activated carbon removes organic matter from wastewater.

Air Sparging

In air sparging, air is injected into the ground below a contaminated area, forming bubbles that rise and carry trapped and dissolved contaminants to the surface where they are captured by a soil vapor extraction system. Air sparging may be a good choice of treatment technology at sites contaminated with solvents and other volatile organic compounds (VOC). *See also Soil Vapor Extraction and Volatile Organic Compound.*

Air Stripping

Air stripping is a treatment system that removes or "strips" VOCs from contaminated groundwater or surface water as air is forced through the water, causing the compounds to evaporate. *See also Volatile Organic Compound.*

American Society for Testing and Materials (ASTM)

The ASTM sets standards for many services, including methods of sampling and testing of hazardous waste and media contaminated with hazardous waste.

Applicable or Relevant and Appropriate Requirement (ARAR)

As defined under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), ARARs are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limits promulgated under Federal or state law that specifically address problems or situations present at a CERCLA site. ARARs are major considerations in setting cleanup goals, selecting a remedy, and determining how to implement that remedy at a CERCLA site. ARARs must be attained at all CERCLA sites unless a waiver is attained. ARARs

are not national cleanup standards for the Superfund program. *See also Comprehensive Environmental Response, Compensation, and Liability Act and Superfund.*

Aquifer

An aquifer is an underground rock formation composed of such materials as sand, soil, or gravel that can store groundwater and supply it to wells and springs.

Aromatics

Aromatics are organic compounds that contain 6-carbon ring structures, such as creosote, toluene, and phenol, that often are found at dry cleaning and electronic assembly sites.

Baseline Risk Assessment

A baseline risk assessment is an assessment conducted before cleanup activities begin at a site to identify and evaluate the threat to human health and the environment. After remediation has been completed, the information obtained during a baseline risk assessment can be used to determine whether the cleanup levels were reached.

Bedrock

Bedrock is the rock that underlies the soil; it can be permeable or non-permeable. *See also Confining Layer and Creosote.*

Best Demonstrated Achievable Technology (BDAT)

A BDAT is a technology that has demonstrated the ability to reduce a particular contaminant to a lower concentration than other currently available technologies. BDATs can change with time as technologies evolve.

Bioremediation

Bioremediation refers to treatment processes that use microorganisms (usually naturally occurring) such as bacteria, yeast, or fungi to break down hazardous substances into less toxic or nontoxic substances. Bioremediation can be used to clean up contaminated soil and water. In situ bioremediation treats the contaminated soil or groundwater in the location in which it is found. For ex situ bioremediation processes, contaminated soil must be excavated or groundwater pumped before they can be treated.

Biosensor

A biosensor is a portable device that uses living organisms, such as enzymes, tissues, microbes, and antibodies, to produce reactions to analytes.

Bioventing

Bioventing is an *in situ* remediation technology that combines soil vapor extraction methods with bioremediation. It uses vapor extraction wells that induce air flow in the subsurface through air injection or through the use of a vacuum. Bioventing can be effective in remediating releases of petroleum products, such as gasoline, jet fuels, kerosene, and diesel fuel. *See also Bioremediation and Soil Vapor Extraction.*

Borehole

A borehole is a hole cut into the ground by means of a drilling rig.

Borehole Geophysics

Borehole geophysics are nuclear or electric technologies used to identify the physical characteristics of geologic formations that are intersected by a borehole.

Brownfields

Brownfields sites are abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.

BTEX

BTEX is the term used for benzene, toluene, ethylbenzene, and xylene-volatile aromatic compounds typically found in petroleum products, such as gasoline and diesel fuel.

Cadmium

Cadmium is a heavy metal that accumulates in the environment. *See also Heavy Metal.*

Carbon Adsorption

Carbon adsorption is a treatment system that removes contaminants from groundwater or surface water as the water is forced through tanks containing activated carbon.

Chemical Dehalogenation

Chemical dehalogenation is a chemical process that removes halogens (usually chlorine) from a chemical contaminant, rendering the contaminant less hazardous. The chemical dehalogenation process can be applied to common halogenated contaminants such as polychlorinated biphenyls (PCB) and dioxins (DDT), which may be present in soil and oils. Dehalogenation can be effective in removing halogens from hazardous organic compounds, such as dioxins, PCBs, and certain chlorinated pesticides. The treatment time is short, energy requirements are moderate, and operation and maintenance costs are relatively low. This technology can be brought to the site, eliminating the need to transport hazardous wastes. *See also Polychlorinated Biphenyl and Dioxin.*

Chlorinator

A chlorinator is a device that adds chlorine, in gas or liquid form, to water or sewage to kill bacteria.

Clean Air Act (CAA)

The CAA is a Federal law passed in 1970 that requires the U.S. Environmental Protection Agency (EPA) to establish regulations to control the release of contaminants to the air to protect human health and environment.

Cleanup

Cleanup is the term used for actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and/or the environment. The term sometimes is used interchangeably with the terms remedial action, removal action, response action, or corrective action.

Clean Water Act (CWA)

CWA is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to U.S. waters. This law gave EPA the authority to set effluent standards on an industry-by-industry basis and to set water quality standards for all contaminants in surface waters.

Colorimetric

Colorimetric refers to chemical reaction-based indicators that are used to produce compound reactions to individual compounds, or classes of compounds. The reactions, such as visible color changes or other easily noted indications, are used to detect and quantify contaminants.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

CERCLA is a Federal law passed in 1980 that created a special tax that funds a trust fund, commonly known as Superfund, to be used to investigate and clean up abandoned or uncontrolled hazardous waste sites. CERCLA required for the first time that EPA step beyond its traditional regulatory role and provide response authority to clean up hazardous waste sites. EPA has primary responsibility for managing cleanup and enforcement activities authorized under CERCLA. Under the program, EPA can pay for cleanup when parties responsible for the contamination cannot be located or are unwilling or unable to perform the work, or take legal action to force parties responsible for contamination to clean up the site or reimburse the Federal government for the cost of the cleanup. *See also Superfund.*

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)

CERCLIS is a database that serves as the official inventory of Superfund hazardous waste sites. CERCLIS also contains information about all aspects of hazardous waste sites, from initial discovery to deletion from the National Priorities List (NPL). The database also maintains information about planned and actual site activities and financial information entered by EPA regional offices. CERCLIS records the targets and accomplishments of the Superfund program and is used to report that information to the EPA Administrator, Congress, and the public. *See also National Priorities List and Superfund.*

Confining Layer

A "confining layer" is a geological formation characterized by low permeability that inhibits the flow of water. *See also Bedrock and Permeability.*

Contaminant

A contaminant is any physical, chemical, biological, or radiological substance or matter present in any media at concentrations that may result in adverse effects on air, water, or soil.

Corrective Measure Study (CMS)

If the potential need for corrective measures is verified during a RCRA Facility Investigation (RFI), the owner or operator of a facility is then responsible for performing a CMS. A CMS is conducted to identify, evaluate, and recommend specific corrective measures based on a detailed engineering evaluation. Using data collected during the RFI, the CMS demonstrates that proposed measures will be effective in controlling the source of contamination, as well as problems posed by the migration of substances from the original source into the environment. The measures also must be assessed in terms of technical feasibility, ability to meet public health protection requirements and protect the environment, possible adverse environmental effects, and institutional constraints. *See also RCRA Facility Investigation.*

Corrosive Wastes

Corrosive wastes include those that are acidic and capable of corroding metal such as tanks, containers, drums, and barrels.

Creosote

Creosote is an oily liquid obtained by the distillation of wood that is used as a wood preservative and disinfectant and often is found at wood preserving sites. *See also Aromatics and Light Nonaqueous Phase Liquid.*

Data Quality Objective (DQO)

DQOs are qualitative and quantitative statements specified to ensure that data of known and appropriate quality are obtained. The DQO process is a series of planning steps, typically conducted during site assessment and investigation, that is designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate. The DQO process involves a logical, step-by-step procedure for determining which of the complex issues affecting a site are the most relevant to planning a site investigation before any data are collected.

Dechlorination

Dechlorination, the process used primarily to treat and destroy halogenated aromatic contaminants, is the chemical reaction that removes halogens (usually chlorine) from the primary structure of the contaminating organic chemical. Dechlorination can treat contaminated liquids, soils, sludges, and sediments, as well as halogenated organics and PCBs, pesticides, and some herbicides.

Dense Nonaqueous Phase Liquid (DNAPL)

A DNAPL is one of a group of organic substances that are relatively insoluble in water and more dense than water. DNAPLs tend to sink vertically through sand and gravel aquifers to the underlying layer.

Dioxin (DDT)

A dioxin is any of a family of compounds known chemically as dibenzo-p-dioxins. They are chemicals released during combustion. Concern about them arises from their potential toxicity and the risk posed by contamination in commercial products. Boilers and industrial furnaces are among the sources of dioxins.

Disposal

Disposal is the final placement or destruction of toxic, radioactive or other wastes; surplus or banned pesticides or other chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental release. Disposal may be accomplished through the use of approved secure landfills, surface impoundments, land farming, deep well injection, ocean dumping, or incineration.

Dual-Phase Extraction

Dual-phase extraction is a technology that extracts contaminants simultaneously from soils in saturated and unsaturated zones by applying soil vapor extraction techniques to contaminants trapped in saturated zone soils. *See also Soil Vapor Extraction.*

Electromagnetic (EM) Geophysics

EM geophysics refers to technologies used to detect spatial (lateral and vertical) differences in subsurface electromagnetic characteristics. The data collected provide information about subsurface environments.

Electromagnetic (EM) Induction

EM induction is a geophysical technology used to induce a magnetic field beneath the earth's surface, which in turn causes a secondary magnetic field to form around nearby objects that have conductive properties, such as ferrous and nonferrous metals. The secondary magnetic field is then used to detect and measure buried debris.

Emergency Removal

An emergency removal is an action initiated in response to a release of a hazardous substance that requires on-site activity within hours of a determination that action is appropriate.

Emerging Technology

An emerging technology is an innovative technology that currently is undergoing bench-scale testing. During bench-scale testing, a small version of the technology is built and tested in a laboratory. If the technology is successful during bench-scale testing, it is demonstrated on a small scale at field sites. If the technology is successful at the field demonstrations, it often will be used full scale at contaminated waste sites. As the technology is used and evaluated at different sites, it is improved continually. *See also Established Technology and Innovative Technology.*

Enforcement Action

An enforcement action is an action undertaken by EPA under its authority granted under various Federal environmental statutes, such as CERCLA, RCRA, CAA, CWA, the Toxic Substances Control Act (TSCA), and others. For example, under CERCLA, EPA may obtain voluntary settlement or compel potentially responsible parties (PRP) to implement removal or remedial actions when releases of hazardous substances have occurred. *See also Comprehensive Environmental Response, Compensation, and Liability Act, Potentially Responsible Party, and Removal Action.*

Engineered Control

An engineered control, such as barriers placed between contamination and the rest of a site, is a method of managing environmental and health risks. Engineered controls can be used to limit exposure pathways.

Environmental Audit

See Phase I Environmental Audit.

Environmental Site Assessment (ESA)

An ESA is the process by which it is determined whether contamination is present on a site.

Established Technology

An established technology is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established. The most frequently used established technologies are incineration, solidification and stabilization, and pump-and-treat technologies for groundwater. *See also Emerging Technology and Innovative Technology.*

Exposure Pathway

An exposure pathway is the route of contaminants from the source of contamination to potential contact with a medium (air, soil, surface water, or groundwater) that represents a potential threat to human health or the environment. Determining whether exposure pathways exist is an essential step in conducting a baseline risk assessment. *See also Baseline Risk Assessment.*

Ex Situ

The term ex situ or "moved from its original place," means excavated or removed.

Filtration

Filtration is a treatment process that removes solid matter from water by passing the water through a porous medium, such as sand or a manufactured filter.

Flame Ionization Detector (FID)

A FID is an instrument often used in conjunction with gas chromatography to measure the change of signal as analytes are ionized by a hydrogen-air flame. It also is used to detect phenols, phthalates, polynuclear aromatic hydrocarbons (PAH), VOCs, and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Fourier Transform Infrared Spectroscope

A fourier transform infrared spectroscope is an analytical air monitoring tool that uses a laser system chemically to identify contaminants.

Fumigant

A fumigant is a pesticide that is vaporized to kill pests. They often are used in buildings and greenhouses. *See also Dioxin.*

Furan

Furan is a colorless, volatile liquid compound used in the synthesis of organic compounds, especially nylon.

Gas Chromatography

Gas chromatography is a technology used for investigating and assessing soil, water, and soil gas contamination at a site. It is used for the analysis of VOCs and semivolatile organic compounds (SVOC). The technique identifies and quantifies organic compounds on the basis of molecular weight, characteristic fragmentation patterns, and retention time. Recent advances in gas chromatography that are considered innovative are portable, weather-proof units that have self-contained power supplies.

Ground-Penetrating Radar (GPR)

GPR is a technology that emits pulses of electromagnetic energy into the ground to measure its reflection and refraction by subsurface layers and other features, such as buried debris.

Groundwater

Groundwater is the water found beneath the earth's surface that fills pores between such materials as sand, soil, or gravel and that often supplies wells and springs. *See also Aquifer.*

Halogenated Organic Compound

A halogenated organic compound is a compound containing molecules of chlorine, bromine iodine, and or fluorine. Halogenated organic compounds were used in high-voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. Many herbicides, pesticides, and degreasing agents are made from halogenated organic compounds.

Hazard Ranking System (HRS)

The HRS is the primary screening tool used by EPA to assess the risks posed to human health or the environment by abandoned or uncontrolled hazardous waste sites. Under the HRS, sites are assigned scores on the basis of the toxicity of hazardous substances that are present and the

potential that those substances will spread through the air, surface, water, or groundwater, taking into account such factors as the proximity of the substance to nearby populations. Scores are used in determining which sites should be placed on the NPL. *See also National Priorities List.*

Hazardous Substance

As defined under CERCLA, a hazardous substance is any material that poses a threat to public health or the environment. The term also refers to hazardous wastes as defined under the Resource Conservation and Recovery Act (RCRA). Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive. If a certain quantity of a hazardous substance, as established by EPA, is spilled into the water or otherwise emitted into the environment, the release must be reported. Under the legislation cited above, the term excludes petroleum, crude oil, natural gas, natural gas liquids, or synthetic gas usable for fuel.

Hazardous and Solid Waste Amendments (HSWA)

HSWA are 1984 amendments to RCRA which required phasing out land disposal of hazardous waste and added minimum technology requirements. *See also Resource Conservation and Recovery Act.*

Heavy Metal

The term heavy metal refers to a group of toxic metals including arsenic, chromium, copper, lead, mercury, silver, and zinc. Heavy metals often are present at industrial sites at which operations have included battery recycling and metal plating.

Herbicide

A herbicide is a chemical pesticide designed to control or destroy plants, weeds, or grasses.

High-Frequency Electromagnetic (EM) Sounding

High-frequency EM sounding, the technology used for nonintrusive geophysical exploration, projects high-frequency electromagnetic radiation into subsurface layers to detect the reflection and refraction of the radiation by various layers of soil. Unlike ground-penetrating radar, which uses pulses, the technology uses continuous waves of radiation. *See also Ground-Penetrating Radar.*

Hydrazine

Hydrazine is a highly toxic liquid used in rocket propellant, agricultural chemicals, drugs, spandex fibers, antioxidants, plating metals on glass and plastic, explosives, and in boiler feedwater. The chemical compound causes a severe explosion hazard when exposed to heat.

Hydrocarbon

A hydrocarbon is an organic compound containing only hydrogen and carbon, often occurring in petroleum, natural gas, and coal.

Hydrogen Sulfide (HS)

HS is a gas emitted during decomposition of organic compounds. It also is a byproduct of oil refining and burning.

Hydrogeology

Hydrogeology is the study of groundwater, including its origin, occurrence, movement, and quality.

Hydrology

Hydrology is the science that deals with the properties, movement, and effects of water found on the earth's surface, in the soil and rocks beneath the surface, and in the atmosphere.

Ignitability

Ignitable wastes can create fires under certain conditions. Examples include liquids, such as solvents that readily catch fire, and friction-sensitive substances.

Immunoassay

Immunoassay is an innovative technology used to measure compound-specific reactions (generally colorimetric) to individual compounds or classes of compounds. The reactions are used to detect and quantify contaminants. The technology is available in field-portable test kits.

Incineration

Incineration is a treatment technology that involves the burning of certain types of solid, liquid, or gaseous materials under controlled conditions to destroy hazardous waste.

Information Repository

An information repository is a location in a public building that is convenient for local residents, such as a public school, city hall, or library, that contains information about a Superfund site, including technical reports and reference documents.

Infrared Monitor

An infrared monitor is a device used to monitor the heat signature of an object, as well as to sample air. It may be used to detect buried objects in soil.

Inorganic Compound

An inorganic compound is a compound that generally does not contain carbon atoms (although carbonate and bicarbonate compounds are notable exceptions), tends to be more soluble in water, and tends to react on an ionic rather than on a molecular basis. Examples of inorganic compounds include various acids, potassium hydroxide, and metals.

Innovative Technology

An innovative technology is a process that has been tested and used as a treatment for hazardous waste or other contaminated materials, but lacks a long history of full-scale use and information about its cost and how well it works sufficient to support prediction of its performance under a variety of operating conditions. An innovative technology is one that is undergoing pilot-scale treatability studies that usually are conducted in the field or the laboratory and require installation of the technology, and provide performance, cost, and design objectives for the technology. Innovative technologies are being used under many Federal and state cleanup programs to treat hazardous wastes that have been improperly released. For example, innovative technologies are being selected to manage contamination (primarily petroleum) at some leaking underground storage sites. *See also Emerging Technology and Established Technology.*

Ion Exchange

Ion exchange, a common method of softening water, depends on the ability of certain materials to remove and exchange ions from water. These ion exchange materials, generally composed of unsoluble organic polymers, are placed in a filtering device. Water softening exchange materials remove calcium and magnesium ions, replacing them with sodium ions.

Insecticide

An insecticide is a pesticide compound specifically used to kill or control the growth of insects. *See also Dioxin.*

In Situ

The term *in situ*, "in its original place," or "on-site", means unexcavated and unmoved. *In situ* soil flushing and natural attenuation are examples of *in situ* treatment methods by which contaminated sites are treated without digging up or removing the contaminants.

In Situ Oxidation

In situ oxidation is an innovative treatment technology that oxidizes contaminants that are dissolved in groundwater and converts them into insoluble compounds.

In Situ Soil Flushing

In situ soil flushing is an innovative treatment technology that floods contaminated soils beneath the ground surface with a solution that moves the contaminants to an area from which they can be removed. The technology requires the drilling of injection and extraction wells on site and reduces the need for excavation, handling, or transportation of hazardous substances. Contaminants considered for treatment by *in situ* soil flushing include heavy metals (such as lead, copper, and zinc), halogenated organic compounds, aromatics, and PCBs. *See also Aromatics, Halogenated Organic Compound, Heavy Metal, and Polychlorinated Biphenyl.*

In Situ Vitrification

In situ vitrification is a soil treatment technology that stabilizes metal and other inorganic contaminants in place at temperatures of approximately 3000°F. Soils and sludges are fused to form a stable glass and crystalline structure with very low leaching characteristics.

Institutional Controls

An institutional control is a legal or institutional measure which subjects a property owner to limit activities at or access to a particular property. They are used to ensure protection of human health and the environment, and to expedite property reuse. Fences, posting or warning signs, and zoning and deed restrictions are examples of institutional controls.

Integrated Risk Information System (IRIS)

IRIS is an electronic database that contains EPA's latest descriptive and quantitative regulatory information about chemical constituents. Files on chemicals maintained in IRIS contain information related to both noncarcinogenic and carcinogenic health effects.

Joint and Several Liability

Under CERCLA, joint and several liability is a concept based on the theory that it may not be possible to apportion responsibility for the harm caused by hazardous waste equitably among potentially responsible parties (PRP) from that defendant. Joint liability means that more than one defendant is liable to the plaintiff. Several liability means that the plaintiff may choose to sue only one of the defendants and recover the entire amount. One PRP therefore can be held liable for the entire cost of cleanup, regardless of the share of waste that PRP contributed. Joint and several liability is used only when harm is indivisible. If defendants can apportion harm, there is no several liability. *See also Potentially Responsible Party and Strict Liability.*

Land Disposal Restrictions (LDR)

LDRs is a RCRA program that restricts the land disposal of RCRA hazardous wastes and requires treatment to promulgated treatment standards. The LDRs may be an important Applicable or Relevant and Appropriate Requirement (ARAR) for Superfund actions. *See also Applicable or Relevant and Appropriate Requirement and Resource Conservation and Recovery Act.*

Landfarming

Landfarming is the spreading and incorporation of wastes into the soil to initiate biological treatment.

Landfill

A sanitary landfill is a land disposal site for nonhazardous solid wastes at which the waste is spread in layers compacted to the smallest practical volume.

Laser-Induced Fluorescence/Cone Penetrometer

Laser-induced fluorescence/cone penetrometer is a field screening method that couples a fiber optic-based chemical sensor system to a cone penetrometer mounted on a truck. The technology can be used for investigating and assessing soil and water contamination.

Leachate

A leachate is a contaminated liquid that results when water collects contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leaching may occur in farming areas and landfills and may be a means of the entry of hazardous substances into soil, surface water, or groundwater.

Lead

Lead is a heavy metal that is hazardous to health if breathed or swallowed. Its use in gasoline, paints, and plumbing compounds has been sharply restricted or eliminated by Federal laws and regulations. *See also Heavy Metal.*

Leaking Underground Storage Tank (LUST)

LUST is the acronym for "leaking underground storage tank." *See also Underground Storage Tank.*

Light Nonaqueous Phase Liquid (LNAPL)

An LNAPL is one of a group of organic substances that are relatively insoluble in water and are less dense than water. LNAPLs, such as oil, tend to spread across the surface of the water table and form a layer on top of the water table.

Magnetometry

Magnetometry is a geophysical technology used to detect disruptions that metal objects cause in the earth's localized magnetic field.

Mass Spectrometry

Mass spectrometry is an analytical process by which molecules are broken into fragments to determine the concentrations and mass/charge ratio of the fragments. Innovative mass spectroscopy units, developed through modification of large laboratory instruments, are sometimes portable, weatherproof units with self-contained power supplies.

Medium

A medium is a specific environment--air, water, or soil--which is the subject of regulatory concern and activities.

Mercury

Mercury is a heavy metal that can accumulate in the environment and is highly toxic if breathed or swallowed. Mercury is a highly toxic substance found in thermometers, measuring devices, pharmaceutical and agricultural chemicals, chemical manufacturing, and electrical equipment. *See also Heavy Metal.*

Mercury Vapor Analyzer

A mercury vapor analyzer is an instrument that provides real-time measurements of concentrations of mercury in the air.

Methane

Methane is a colorless, nonpoisonous, flammable gas created by anaerobic decomposition of organic compounds.

Migration Pathway

A migration pathway is a potential path or route of contaminants from the source of contamination to contact with human populations or the environment. Migration pathways include air, surface water, groundwater, and land surface. The existence and identification of all potential migration pathways must be considered during assessment and characterization of a waste site.

Mixed Waste

Mixed waste is low-level radioactive waste contaminated with hazardous waste that is regulated under RCRA. Mixed waste can be disposed only in compliance with the requirements under RCRA that govern disposal of hazardous waste and with the RCRA land disposal restrictions, which require that waste be treated before it is disposed of in appropriate landfills.

Monitoring Well

A monitoring well is a well drilled at a specific location on or off a hazardous waste site at which groundwater can be sampled at selected depths and studied to determine the direction of groundwater flow and the types and quantities of contaminants present in the groundwater.

National Contingency Plan (NCP)

The NCP, formally the National Oil and Hazardous Substances Contingency Plan, is the major regulatory framework that guides the Superfund response effort. The NCP is a comprehensive body of regulations that outlines a step-by-step process for implementing Superfund responses and defines the roles and responsibilities of EPA, other Federal agencies, states, private parties, and the communities in response to situations in which hazardous substances are released into the environment. *See also Superfund.*

National Pollutant Discharge Elimination System (NPDES)

NPDES is the primary permitting program under the Clean Water Act, which regulates all discharges to surface water. It prohibits discharge of pollutants into waters of the United States unless EPA, a state, or a tribal government issues a special permit to do so.

National Priorities List (NPL)

The NPL is EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial response under Superfund. Inclusion of a site on the list is based primarily on the score the site receives under the HRS. Money from Superfund can be used for cleanup only at sites that are on the NPL. EPA is required to update the NPL at least once a year. *See also Hazard Ranking System and Superfund.*

National Response Center (NRC)

The NRC, staffed by the U.S. Coast Guard, is a communications center that receives reports of discharges or releases of hazardous substances into the environment. The U.S. Coast Guard in turn, relays information about such releases to the appropriate Federal agency.

Natural Attenuation

Natural attenuation is an approach to cleanup that uses natural processes to contain the spread of contamination from chemical spills and reduce the concentrations and amounts of pollutants in contaminated soil and groundwater. Natural subsurface processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, are allowed to reduce concentrations of contaminants to acceptable levels. An in situ treatment method that leaves the contaminants in place while those processes occur, natural attenuation is being used to clean up petroleum contamination from leaking underground storage tanks (LUST) across the country.

Nitric Oxide

Nitric oxide is a gas formed by combustion under high temperature and high pressure in an internal combustion engine.

Nonaqueous Phase Liquid (NAPL)

NAPLs are organic substances that are relatively insoluble in water and are less dense than water. *See also Dense Nonaqueous Phase Liquid and Light Nonaqueous Phase Liquid.*

Non-Point Source

The term non-point source is used to identify sources of pollution that are diffuse and do not have a point of origin or that are not introduced into a receiving stream from a specific outlet. Common non-point sources are rain water, runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings.

Operation and Maintenance (O&M)

O&M refers to the activities conducted at a site, following remedial actions, to ensure that the cleanup methods are working properly. O&M activities are conducted to maintain the effectiveness of the remedy and to ensure that no new threat to human health or the environment arises. The state or PRP assumes responsibility for O&M, which may include such activities as groundwater and air monitoring, inspection and maintenance of the treatment equipment remaining on site, and maintenance of any security measures or institutional controls.

Organic Chemical or Compound

An organic chemical or compound is a substance produced by animals or plants that contains mainly carbon, hydrogen, and oxygen.

Ozone

Ozone is a form of oxygen found naturally which provides a protective layer shielding the earth from the harmful health effects on human health and the environment from ultraviolet radiation. Ozone is a chemical oxidant and a major component of smog in the troposphere, the earth's atmospheric layer extending 7 to 10 miles from the earth's surface. Ozone can have a serious effect on the human respiratory system and is one of the most prevalent and widespread of all the criteria pollutants for which the Clean Air Act required EPA to set standards.

Pentachlorophenol (PCP)

PCP, a chemical compound containing carbon, chlorine, oxygen, and hydrogen, is a contaminant used in feed stock material and chemical manufacturing.

Permeability

Permeability is a characteristic that represents a qualitative description of the relative ease with which rock, soil, or sediment will transmit a fluid (liquid or gas).

Pesticide

A pesticide is a substance or mixture of substances intended to prevent or mitigate infestation by, or destroy or repel, any pest. Pesticides can accumulate in the food chain and/or contaminate the environment if misused. *See also Dioxin.*

Phase I Environmental Audit

A Phase I environmental audit is an initial environmental investigation that is limited to a historical records search to determine ownership of a site and to identify the kinds of chemical processes that were carried out at the site. A Phase I audit includes a site visit, but does not include any sampling. If such an audit identifies no significant concerns, Phase II and III audits are not necessary.

Phase II Environmental Audit

A Phase II environmental audit is an investigation that includes tests performed at the site to confirm the location and identity of environmental hazards. The audit includes preparation of a report that includes recommendations for cleanup alternatives.

Phase III Environmental Audit

A Phase III environmental audit is the third-step in the audit that includes the removal of contaminated materials from a site and their legal disposal.

Phenols

A phenol is one of a group of organic compounds that are byproducts of petroleum refining, tanning, and textile, dye, and resin manufacturing. Low concentrations of phenols cause taste and odor problems in water; higher concentrations may be harmful to human health or the environment.

Photoionization Detector (PID)

A PID is a nondestructive detector, often used in conjunction with gas chromatography, that measures the change of signal as analytes are ionized by an ultraviolet lamp. The PID also is used to detect VOCs and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Phytoremediation

Phytoremediation is an innovative treatment technology that uses plants and trees to clean up contaminated soil and water. Plants can break down, or degrade, organic pollutants or stabilize metal contaminants by acting as filters or traps. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polycyclic aromatic hydrocarbons, and landfill leachates. Its use generally is limited to sites at which concentrations of contaminants are relatively low and contamination is found in shallow soils, streams, and groundwater.

Plasma High-Temperature Metals Recovery

Plasma high-temperature metals recovery is a thermal treatment process that purges contaminants from solids and soils such as metal fumes and organic vapors. The vapors can be burned as fuel, and the metal fumes can be recovered and recycled. This innovative treatment technology is used to treat contaminated soil and groundwater.

Plume

A plume is a visible or measurable emission or discharge of a contaminant from a given point of origin into any medium. The term also is used to refer to measurable and potentially harmful radiation leaking from a damaged reactor.

Point Source

A point source is a stationary location or fixed facility from which pollutants are discharged or emitted or any single, identifiable discharge point of pollution, such as a pipe, ditch, or smokestack.

Polychlorinated Biphenyl (PCB)

PCBs are a group of toxic, persistent chemicals, produced by chlorination of biphenyl, that once were used in high voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. These contaminants

typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Further sale or use of PCBs was banned in 1979.

Polynuclear Aromatic Hydrocarbon (PAH)

A PAH is a chemical compound that contains more than one fused benzene ring. They are commonly found in petroleum fuels, coal products, and tar.

Potentially Responsible Party (PRP)

A PRP is an individual or company (such as owners, operators, transporters, or generators of hazardous waste) that is potentially responsible for, or contributing to, the contamination problems at a Superfund site. Whenever possible, EPA requires PRPs, through administrative and legal actions, to clean up hazardous waste sites they have contaminated. *See also Superfund.*

Preliminary Assessment and Site Investigation (PA/SI)

A preliminary assessment (PA) is the process of collecting and reviewing available information about a known or suspected hazardous waste site or release. The PA usually includes a visit to the site.

Presumptive Remedies

Presumptive remedies are preferred technologies for common categories of CERCLA sites that have been identified through historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation.

Pump and Treat

Pump and treat is a general term used to describe remediation methods that involve the pumping of groundwater to the surface for treatment. It is one of the most common methods of treating polluted aquifers and groundwater.

Quality Assurance and Quality Control (QA/QC)

QA/QC is a system of procedures, checks, audits, and corrective actions applied to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.

Radioactive Waste

Radioactive waste is any waste that emits energy as rays, waves, or streams of energetic particles. Sources of such wastes include nuclear reactors, research institutions, and hospitals.

Radionuclide

A radionuclide is a radioactive element characterized according to its atomic mass and atomic number, which can be artificial or naturally occurring. Radionuclides have a long life as soil or water pollutants. Radionuclides cannot be destroyed or degraded; therefore, applicable technologies involve separation, concentration and volume reduction, immobilization, or vitrification. *See also Solidification and Stabilization.*

Radon

Radon is a colorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium atoms. *See also Radioactive Waste and Radionuclide.*

RCRA Facility Assessment (RFA)

A RFA is performed at a facility to determine the existence of any continuous or non-continuous releases of wastes. During the RFA, EPA or state regulators gather information on solid waste management units and other areas of concern at RCRA facilities, evaluate this information to determine whether there are releases that warrant further investigation and action, and determine the need to proceed to a RCRA Facility Investigation (RFI). *See also Resource Conservation and Recovery Act.*

RCRA Facility Investigation (RFI)

The purpose of a RFI is to gather sufficient data at a facility to fully characterize the nature, extent, and rate of migration of contaminant releases identified in the RCRA Facility Assessment (RFA). The data generated during the RFI is used to determine the potential need for corrective measures and to aid in the selection and implementation of these measures. *See also Corrective Measure Study and Resource Conservation and Recovery Act.*

Reactive Wastes

Reactive wastes are unstable under normal conditions. They can create explosions and/or toxic fumes, gases, and vapors when mixed with water.

Record of Decision (ROD)

A record of decision (ROD) is a legal, technical, and public document that explains which cleanup alternative will be used at a site. The ROD is based on information and technical analysis generated during the remedial investigation and feasibility study (RI/FS) and consideration of public comments and community concerns. *See also Preliminary Assessment and Site Investigation and Remedial Investigation and Feasibility Study.*

Release

A release is any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical or extremely hazardous substance, as defined under RCRA. *See also Resource Conservation and Recovery Act.*

Remedial Design and Remedial Action (RD/RA)

The RD/RA is the step in the cleanup process that follows the remedial investigation and feasibility study (RI/FS) and selection of a remedy. A remedial design (RD) is the preparation of engineering plans and specifications to properly and effectively implement the remedy. The remedial action (RA) is the actual construction or implementation of the remedy. *See also Remedial Investigation and Feasibility Study.*

Remedial Investigation and Feasibility Study (RI/FS)

The RI/FS is the step in the cleanup process that is conducted to gather sufficient information to support the selection of a site remedy that will reduce or eliminate the risks associated with contamination at the site. The remedial investigation (RI) involves site characterization -- collection of data and information necessary to characterize the nature and extent of contamination at the site. The RI also determines whether the contamination presents a significant risk to human health or the environment. The feasibility study (FS) focuses on the development of specific response alternatives for addressing contamination at a site.

Removal Action

A removal action usually is a short-term effort designed to stabilize or clean up a hazardous waste site that poses an immediate threat to human health or the environment. Removal actions include removing tanks or drums of hazardous substances

that were found on the surface and installing drainage controls or security measures, such as a fence at the site. Removal actions also may be conducted to respond to accidental releases of hazardous substances. CERCLA places time and money constraints on the duration of removal actions. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Reportable Quantity (RQ)

The RQ is the quantity of hazardous substances that, when released into the environment, can cause substantial endangerment to public health or the environment. Under CERCLA, the Federal government must be notified when quantities equaling or exceeding RQs specified in regulations are released.

Resin

Resins are solids or semi-solids of plant origin used principally in lacquers, varnishes, inks, adhesives, synthetic plastics, and pharmaceuticals.

Resource Conservation and Recovery Act (RCRA)

RCRA is a Federal law enacted in 1976 that established a regulatory system to track hazardous substances from their generation to their disposal. The law requires the use of safe and secure procedures in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent the creation of new, uncontrolled hazardous waste sites.

Response Action

A response action is a short-term removal action or a long-term remedial response, authorized under CERCLA that is taken at a site to address releases of hazardous substances.

Risk Communication

Risk communication, the exchange of information about health or environmental risks among risk assessors, risk managers, the local community, news media and interest groups, is the process of informing members of the local community about environmental risks associated with a site and the steps that are being taken to manage those risks.

Sanborn Map

A Sanborn map is a record kept for insurance purposes that shows, for a specific property, the locations of such items as underground storage tanks (UST), buildings, and areas where chemicals have been used for certain industrial processes. A Phase I environmental audit includes a review of Sanborn maps. *See also Phase I Environmental Audit.*

Saturated Zone

The saturated zone is the area beneath the surface of the land in which all openings are filled with water at greater than atmospheric pressure.

Seismic Reflection and Refraction

Seismic reflection and refraction is a technology used to examine the geophysical features of soil and bedrock, such as debris, buried channels, and other features.

Semi-Volatile Organic Compound (SVOC)

SVOCs, composed primarily of carbon and hydrogen atoms, have boiling points greater than 200°C. Common SVOCs include PCPs and phenol. *See also Phenol and Polychlorinated Biphenyl.*

Sludge

Sludge is a semisolid residue from air or water treatment processes. Residues from treatment of metal wastes and the mixture of waste and soil at the bottom of a waste lagoon are examples of sludge, which can be a hazardous waste.

Slurry-Phase Bioremediation

Slurry-phase bioremediation, a treatment technology that can be used alone or in conjunction with other biological, chemical, and physical treatments, is a process through which organic contaminants are converted to innocuous compounds. Slurry-phase bioremediation can be effective in treating various SVOCs and nonvolatile organic compounds, as well as fuels, creosote, pentachlorophenols (PCP), and PCBs.

Soil Boring

Soil boring is a process by which a soil sample is extracted from the ground for chemical, biological, and analytical testing to determine the level of contamination present.

Soil Gas

Soil gas consists of gaseous elements and compounds that occur in the small spaces between particles of the earth and soil. Such gases can move through or leave the soil or rock, depending on changes in pressure.

Soil Vapor Extraction (SVE)

SVE, the most frequently selected innovative treatment at Superfund sites, is a process that physically separates contaminants from soil in a vapor form by exerting a vacuum through the soil formation. Soil vapor extraction removes VOCs and some SVOCs from soil beneath the ground surface.

Soil Washing

Soil washing is an innovative treatment technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils, removes hazardous contaminants, and concentrates the contaminants into a smaller volume. The technology is used to treat a wide range of contaminants, such as metals, gasoline, fuel oils, and pesticides. Soil washing is a relatively low-cost alternative for separating waste and minimizing volume as necessary to facilitate subsequent treatment. It is often used in combination with other treatment technologies. The technology can be brought to the site, thereby eliminating the need to transport hazardous wastes.

Solidification and Stabilization

Solidification and stabilization are the processes of removing wastewater from a waste or changing it chemically to make the waste less permeable and susceptible to transport by water. Solidification and stabilization technologies can immobilize many heavy metals, certain radionuclides, and selected organic compounds, while decreasing the surface area and permeability of many types of sludge, contaminated soils, and solid wastes.

Solvent

A solvent is a substance, usually liquid, that is capable of dissolving or dispersing one or more other substances.

Solvent Extraction

Solvent extraction is an innovative treatment technology that uses a solvent to separate or remove hazardous organic contaminants from oily-type wastes, soils, sludges, and sediments. The technology does not destroy contaminants, but concentrates them so they can be recycled or destroyed more easily by another technology. Solvent extraction has been shown to be effective in treating sediments, sludges, and soils that contain primarily organic contaminants, such as PCBs, VOCs, halogenated organic compounds, and petroleum wastes. Such contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Solvent extraction is a transportable technology that can be brought to the site. *See also Halogenated Organic Compound, Polychlorinated Biphenyl, and Volatile Organic Compound.*

Strict Liability

Strict liability is a concept under CERCLA that empowers the Federal government to hold PRPs liable without proving that the PRPs were at fault and without regard to a PRP's motive. PRPs can be found liable even if the problems caused by the release of a hazardous substance were unforeseeable, the PRPs acted in good faith, and state-of-the-art hazardous waste management practices were used at the time the materials were disposed of. *See also Potentially Responsible Party.*

Surfactant Flushing

Surfactant flushing is an innovative treatment technology used to treat contaminated groundwater. Surfactant flushing of NAPLs increases the solubility and mobility of the contaminants in water so that the NAPLs can be biodegraded more easily in an aquifer or recovered for treatment aboveground. *See also Nonaqueous Phase Liquid.*

Surface Water

Surface water is all water naturally open to the atmosphere, such as rivers, lakes, reservoirs, streams, and seas.

Superfund

Superfund is the trust fund that provides for the cleanup of hazardous substances released into the environment, regardless of fault. The Superfund was established under CERCLA and subsequent amendments to CERCLA. The term Superfund also is used to refer to cleanup programs designed and conducted under CERCLA and its subsequent amendments. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Amendment and Reauthorization Act (SARA)

SARA is the 1986 act amending CERCLA that increased the size of the Superfund trust fund and established a preference for the development and use of permanent remedies, and provided new enforcement and settlement tools. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Innovative Technology Evaluation (SITE) Program

The SITE program is an effort established by EPA in 1986 to advance the development, evaluation, and commercialization of innovative treatment technologies for assessing and cleaning up hazardous waste sites. The program provides an opportunity for technology developers to demonstrate their technologies' ability to successfully process and remediate hazardous waste. The SITE program has four components—the Emerging Technology Program, the Demonstration Program, the Monitoring and Measurement Technologies Program, and the Technology Transfer Program.

Thermal Desorption

Thermal desorption is an innovative treatment technology that heats soils contaminated with hazardous wastes to temperatures from 200 to 1,000°F so that contaminants that have low boiling points will vaporize and separate from the soil. The vaporized contaminants then are collected for further treatment or destruction, typically by an air emissions treatment system. The technology is most effective at treating VOCs, SVOCs and other organic contaminants, such as PCBs, PAHs, and pesticides. It is effective in separating organics from refining wastes, coal tar wastes, waste from wood treatment, and paint wastes. It also can separate solvents,

pesticides, PCBs, dioxins, and fuel oils from contaminated soil. *See also Polyaromatic Hydrocarbon, Polychlorinated Biphenyl, Semivolatile Organic Compound, and Volatile Organic Compound.*

Total Petroleum Hydrocarbon (TPH)

TPH refers to a measure of concentration or mass of petroleum hydrocarbon constituents present in a given amount of air, soil, or water.

Toxicity

Toxicity is a quantification of the degree of danger posed by a substance to animal or plant life.

Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP is a testing procedure used to identify the toxicity of wastes and is the most commonly used test for degree of mobilization offered by a solidification and stabilization process. Under this procedure, a waste is subjected to a process designed to model the leaching effects that would occur if the waste was disposed of in a RCRA Subtitle D municipal landfill. *See also Solidification and Stabilization.*

Toxic Substance

A toxic substance is a chemical or mixture that may present an unreasonable risk of injury to health or the environment.

Toxic Substances Control Act (TSCA)

TSCA was enacted in 1976 to test, regulate, and screen all chemicals produced or imported into the U.S. TSCA requires that any chemical that reaches the consumer marketplace be tested for possible toxic effects prior to commercial manufacture. Any existing chemical that poses health and environmental hazards is tracked and reported under TSCA.

Treatment, Storage, and Disposal (TSD) Facilities

TSDs are facilities at which hazardous substances are treated, stored, or disposed. TSD facilities are regulated by EPA and states under RCRA. *See also Resource Conservation and Recovery Act.*

Treatment Wall (also Passive Treatment Wall)

A treatment wall is a structure installed underground to treat contaminated groundwater found at hazardous waste sites. Treatment walls, also called passive treatment walls, are put in place by constructing a giant trench across the flow path of contaminated groundwater and filling the trench

with one of a variety of materials carefully selected for the ability to clean up specific types of contaminants. As the contaminated groundwater passes through the treatment wall, the contaminants are trapped by the treatment wall or transformed into harmless substances that flow out of the wall. The major advantage of using treatment walls is that they are passive systems that treat the contaminants in place so the property can be put to productive use while it is being cleaned up. Treatment walls are useful at some sites contaminated with chlorinated solvents, metals, or radioactive contaminants.

Trichloroethylene (TCE)

TCE is a stable, low-boiling colorless liquid that is used as a solvent, metal degreasing agent, and in other industrial applications.

Underground Storage Tank (UST)

A UST is a tank located entirely or partially underground that is designed to hold gasoline or other petroleum products or chemical solutions.

Unsaturated Zone

The unsaturated zone is the area between the land surface and the uppermost aquifer (or saturated zone). The soils in an unsaturated zone may contain air and water.

Vadose Zone

The vadose zone is the area between the surface of the land and the equifer water table in which the moisture content is less than the saturation point and the pressure is less than atmospheric. The openings (pore spaces) also typically contain air or other gases.

Vapor

Vapor is the gaseous phase of any substance that is liquid or solid at atmospheric temperatures and pressures. Steam is an example of a vapor.

Volatile Organic Compound (VOC)

A VOC is one of a group of carbon-containing compounds that evaporate readily at room temperature. Examples of volatile organic compounds include trichloroethane, trichloroethylene, benzene, toluene, ethylbenzene, and xylene (BTEX). These contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes.

Volatilization

Volatilization is the process of transfer of a chemical from the aqueous or liquid phase to the gas phase. Solubility, molecular weight, and vapor pressure of the liquid and the nature of the gas-liquid affect the rate of volatilization.

Voltammetric Stripping

Voltammetric stripping is a field-portable technology that uses electrochemistry to detect and quantify metals in environmental samples. Specific metals can be targeted for detection and quantification by the technology, which generally is applied to water samples.

Voluntary Cleanup Program (VCP)

A VCP is a formal means established by many states to facilitate assessment, cleanup, and redevelopment of Brownfields sites. VCPs typically address the identification and cleanup of potentially contaminated sites that are not on the NPL. Under VCPs, owners or developers of a site are encouraged to approach the state voluntarily to work out a process by which the site can be readied for development. Many state VCPs provide technical assistance, liability assurances, and funding support for such efforts. *See also National Priorities List.*

Wastewater

Wastewater is spent or used water from an individual home, a community, a farm, or an industry that contains dissolved or suspended matter.

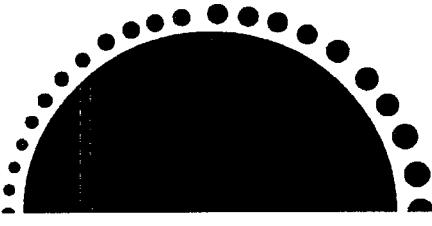
Water Table

A water table is the boundary between the saturated and unsaturated zones beneath the surface of the earth, the level of groundwater, and generally is the level to which water will rise in a well. *See also Aquifer and Groundwater.*

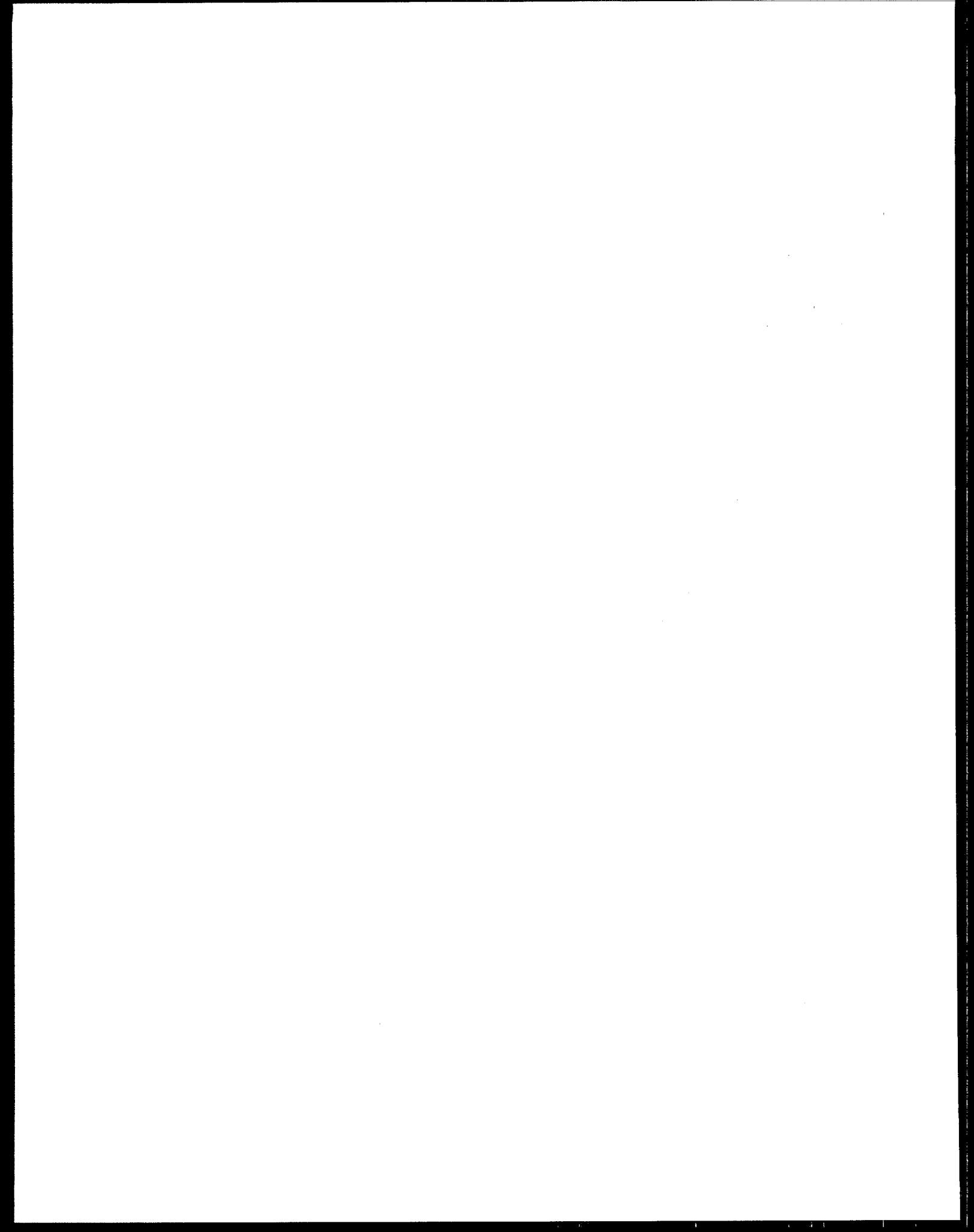
X-Ray Fluorescence Analyzer

An x-ray fluorescence analyzer is a self-contained, field-portable instrument, consisting of an energy dispersive x-ray source, a detector, and a data processing system that detects and quantifies individual metals or groups of metals.

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APPENDIX C



Appendix C
**LIST OF BROWNFIELDS
AND TECHNICAL SUPPORT CONTACTS**

The lists included in this appendix identify contacts at the state and EPA regional levels, as well as EPA technical support staff in the Technology Innovation Office and the Office of Research and Development. The individuals are available to assist cleanup and redevelopment efforts at Brownfields sites.



State Brownfields Contacts C-2



EPA Regional Brownfields Coordinators C-6



EPA Technical Support C-7

STATE BROWNFIELDS CONTACTS

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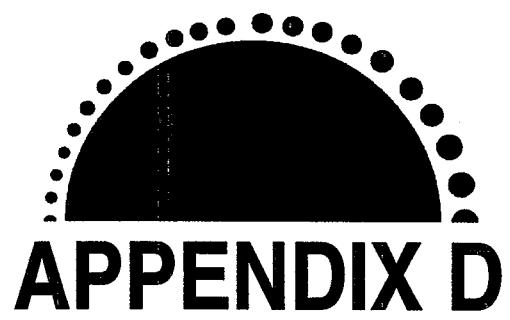
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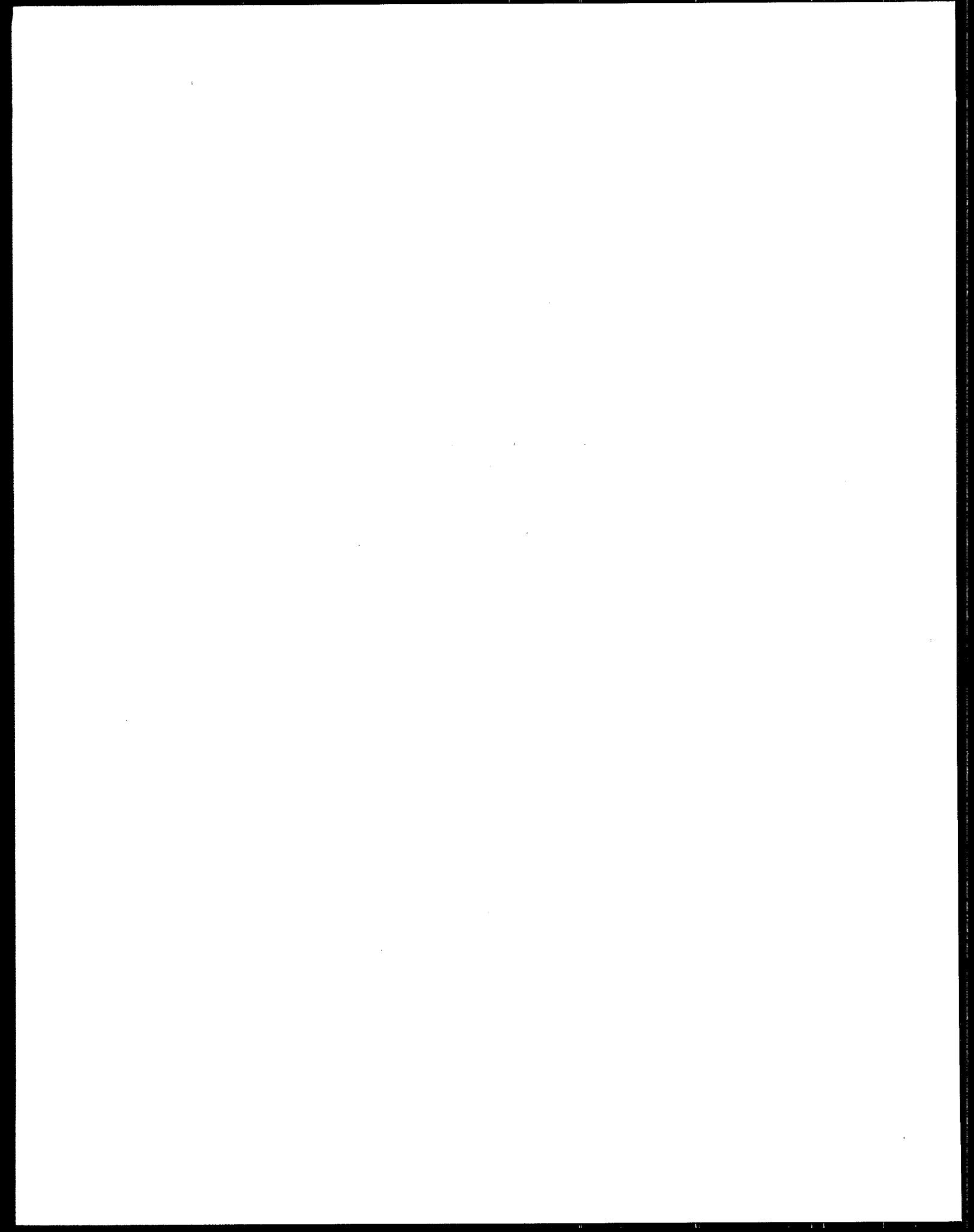
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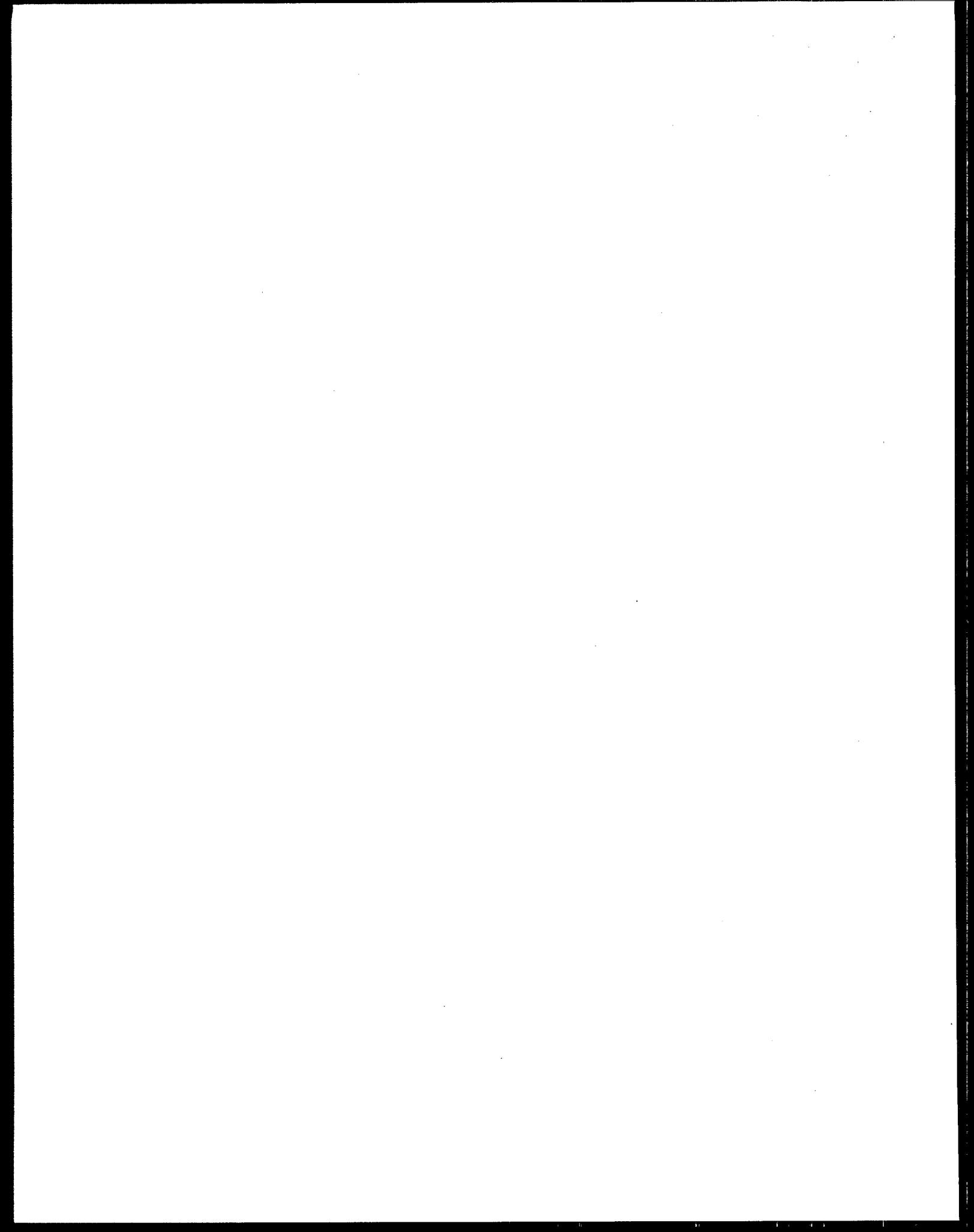
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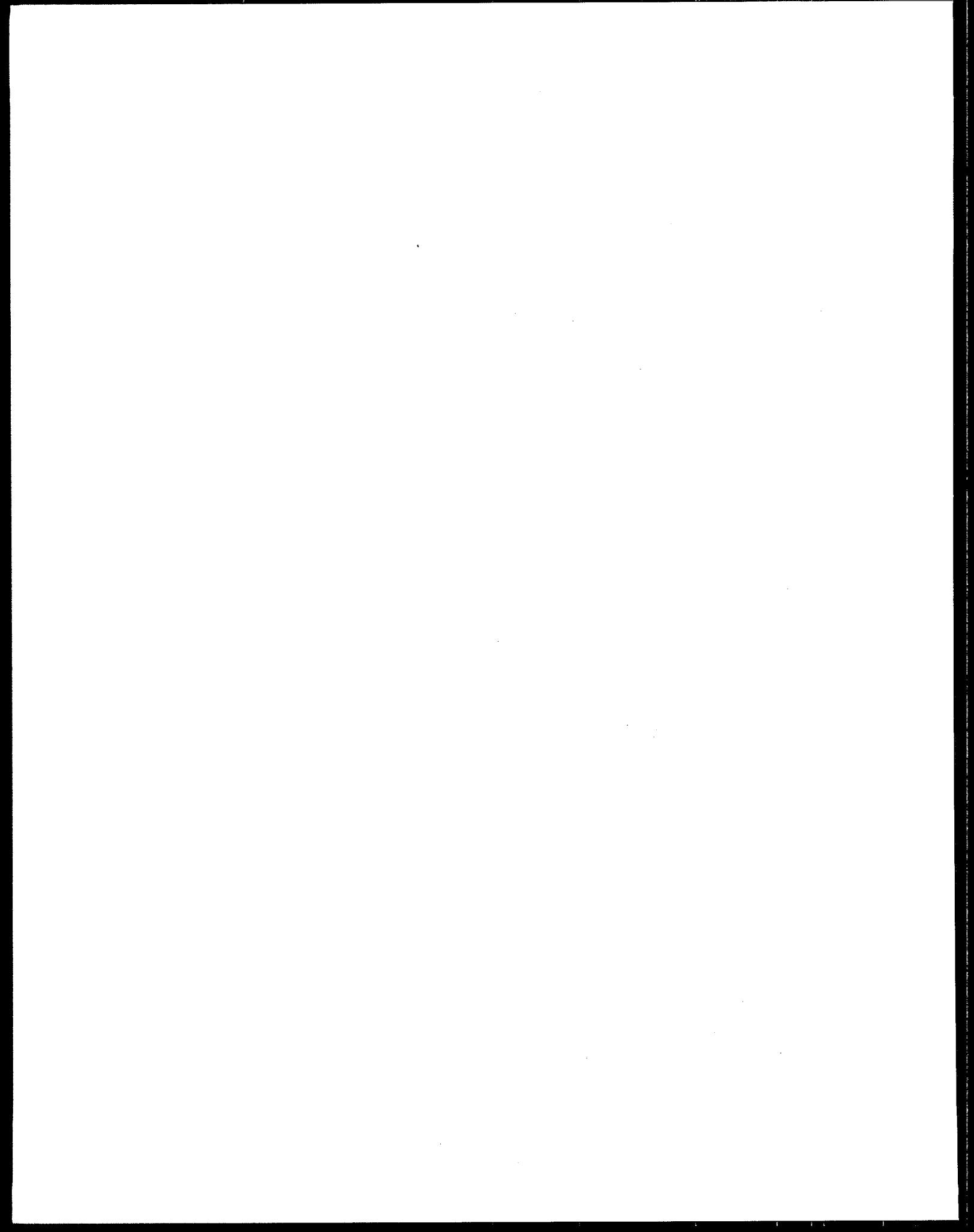
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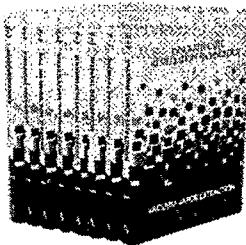


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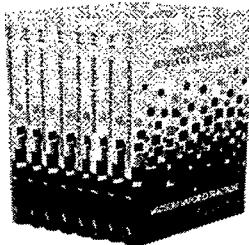
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